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ABSTRACT

This document assesses the specific character of the research systems in the Netherlands, Norway, Sweden, Switzerland, and Belgium in light of their institutional mechanisms and the way they function. The five articles presented concern international dimensions - national traditions and research policies; university research in a teaching oriented environment; research in the government sector; research in industry, sicnece, and university; and the place of the foundations in the research system. No definite conclusions are indicated, however, it is suggested that the changes that have occurred in the organization of scientific work and in the nature and scope of the facilities it requires make it necessary to reshape many research institutions, particularly in industry and the universities. An effort of this kind can only be planned and carried out under the sponsorship of the state and in the light of national interests. This necessitates the development of government decisionmaking mechanisms with wide powers and further investigation to ascertain the conditions under which research policies geared to economic objectives will have to be determined in the coming years. (Author/MJM)

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under the direction of
J.-J. Salomon

the research system

Comparative Survey of the Organisation and Financing of Fundamental Research

VOLUME II

BELGIUM, NETHERLANDS, NORWAY, SWEDEN, SWITZERLAND

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PRELIMINARY REMARKS

This second volume of the survey of the Research System brings out even more clearly than the first that there is no single or exclusive pattern in the organisation, financing and orientation of scientific activity. Traditions, institutions and structures form a context and impose policies which bear no resemblance to those of the "larger" European countries. In the countries studied here, whatever may have been the constraints of international competition, research and development policies have pursued a steady path, whereas the first volume showed a saw-tooth pattern full of sudden changes and sharp breaks. To the very extent that the major problem of all industrialised countries, large and small, is to adapt their scientific research structures and resources to the new needs arising out of social concerns, the experience of the smaller European countries may well afford the bigger countries examples of solutions which are not only more flexible and efficient but less expensive.

The choice of the five countries which are the subject of this study may seem somewhat arbitrary. The intention in fact was to choose the most representative possible sample of countries whose drive and influence in international competition were measured not by their size but by their achievements. These achievements are not only substantial but in many sectors they reveal a climate which is particularly favourable to innovation. The institutions, universities, industrial resources and policies of each of these countries have their specific characteristics; despite this diversity, the way they have handled similar problems of organisation, co-ordination and orientation, affords a body of experience the common lessons of which are well worth considering and even adopting.

The successes they have achieved, however, can be followed up only at the cost of a number of adjustments dictated by economic and social change. These adjustments, which concern all industrial countries whatever their size, call for the adaptation of the structures of scientific research, the scope, direction and procedure of which it is now important to define. This will be the subject of the third volume in this survey which will compare the situation in North America and Europe and will attempt to determine how and to what extent scientific research is likely to be affected by the new concern with social issues. Only when this assessment has been completed will it be possible to set forth the conclusions and recommendations of this overall comparative survey.

The picture of the research system we present here would be incomplete if mention were not made of the role which the private foundations are being increasingly called upon to play in supporting and even in orienting certain research. A whole section has accordingly been devoted to a study of the functions and influence of the foundations, once again clearly demonstrating that the real importance of institutions concerned in supporting scientific research is often qualitative rather than quantitative.

We should like to thank all those— too numerous to mention— who helped in carrying out the survey, facilitated contacts and visits and extended a warm and rewarding welcome to the authors. The people concerned— government officials, university members, industrialists and representatives of foundations— have all played an important part in the production of this volume for which, it need hardly be said, the authors take full responsibility.

Jean-Jacques SALOMON.

Part I

INTERNATIONAL DIMENSIONS: NATIONAL TRADITIONS AND RESEARCH POLICIES

by
Georges FERNÉ

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INTRODUCTION

How much does the organisation of the research systems in Belgium, the Netherlands, Norway, Sweden and Switzerland differ from that previously described in France, Germany and the United Kingdom ?[1] History and political geography point to an immediate reply: the first five countries have not exercised an influence on world scientific progress comparable to that of the last three, although their influence cannot be measured solely by their size: the Netherlands and Switzerland, for example, have produced a relatively high number of internationally famous scientists. On the whole, however, the disproportion between the available resources and the international ambitions of the two groups of countries today lends a very special colour to the scientific and technological efforts of the five countries compared with those of the other three.

We shall not dwell on these observations, although their explanatory value remains essential. We shall assess the specific character of the research systems in the five countries under review purely in the light of their institutional mechanisms and the way they function.

From this point of view, the differences from the state of affairs in France, Germany and the United Kingdom are striking. Whereas in the three larger countries there were manifest signs of unrest among scientific and engineering circles, in the five countries there is a feeling of continuity without any major interruption; whereas the three countries seem to be tending mainly towards the adoption of policies for the conversion of structures unfavourable to innovation, the five others seem to be tending mainly to enlarge the objectives assigned to an effective and dynamic scientific and technological enterprise.

1. Continuity

Science policies in Germany, France and the United Kingdom have been marked over the last decade by a stabilisation of the growth in resources allocated to R & D and by an effort of reorganisation and orientation. In this new climate a certain unrest began to emerge among scientists mainly owing to the fear of a scientific "recession" and a sharp and sweeping readjustment of government priorities. These anxieties about the whole future substance of research efforts were, moreover, accompanied in the three countries by a certain lack of enthusiasm towards government efforts to modify the research organisation itself, either by creating new competing institutions, or by encouraging the regrouping of disciplines or, through the distribution of grants, challenging the traditional social and professional hierarchies.

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[1] *The Research System*, Volume I, OECD, Paris, 1972.

On the whole, therefore, the unrest among scientific circles in the three countries seemed more marked in proportion to changes in funding patterns and to the degree of effort made to bring scientific activities more directly under the influence of the political authorities.

With regard to the essential objectives of scientific and technical activity, none of the five countries discussed here has recently experienced such sweeping adjustment as those observed in the first three countries reviewed. It is true that four of them are not engaged upon any technological enterprise comparable to the nuclear or military efforts of the other powers. Only Sweden has devoted any substantial part of its scientific and technological potential to its defence policy. Any reduction in research appropriations in this sector— which many observers think unlikely— would nevertheless probably not prejudice support for university fundamental research, but rather the contrary.

Thus, for the last ten years ,or so, advanced research in these five countries seems to have enjoyed continuous growth in an atmosphere of liberalism which leaves private enterprise free to choose the fields of its scientific initiatives. On the whole, the development of research has enjoyed, from the point of view of direct funding, a steadier progression than in many other countries. It remains, nevertheless, that events external to the research system proper— for instance the growth of enrolments in higher education— may have caused serious difficulties in many laboratories[2].

There has been little government intervention in the performance of research itself; on the whole the attitude of the authorities in respect to financing has mainly been one of passive response to the proposals submitted by researchers. Belgium is, however, an exception to this attitude; this country was in fact one of the first to formulate a science policy designed to bring research activities into line with national potential and ambitions. In this respect, and in connection with its explicitly "voluntarist" policy designed to strengthen the efficiency of research structures and to ensure the economic regrouping of effort, Belgium seems to be the only one of the five countries reviewed in which a certain unrest can be detected in traditional scientific circles, comparable to that found in France and the United Kingdom. This feeling is, however, much less strong in Belgium, no doubt because of the absence of major national programmes liable to "agonising reappraisal" in the light of economic circumstances.

There is therefore really nothing to contradict this impression of continuity of effort in the five countries. This stability, however, should not be allowed to disguise the powerful and sustained drive which has yielded rich results in each of the five countries in science as well as in education and in the economy. General sensitivity to national industrial requirements has often overcome structural stability and encouraged Dutch, Swedish and Swiss researchers to switch over rapidly where appropriate to new fields of economic importance calculated to strengthen the world position of national industries. The number of such successes must not hide, however, the cases where so-called "science-based" industrial branches have not known how to (or been able to) foresee and meet in time new foreign technological challenges.

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[2] See Part II, Introduction.

An essentially liberal conception of the relations between science and industry therefore implies spontaneous adaptability on both sides in response to a rapid understanding of newly emerging restraints or opportunities. In countries with an extremely dynamic economic infrastructure this approach has, in fact, proved very fruitful. Is it, however, consistent with the new objectives of a very different character which are increasingly being suggested for science in most industrialised countries with a view to meeting a new type of collective needs ?[3]

2. The enlargement of objectives

The most ambitious science policies of the industrialised countries have generally been marked by the definition of a broad range of technological goals. The execution of these programmes has, in particular, been expected to provide an overall stimulus to innovation in firms, public services and, more generally, the whole national community. Experience accumulated over the last ten years has thrown some doubt on these initial hopes; the structural obstacles to innovation have often proved to be more constraining and tougher than had been thought and the most ambitious technological undertakings of governments have not often led to the desired social and economic transformations. Thus, a first balance-sheet of the fundamental research policies of countries such as France, Germany and the United Kingdom leads to the conclusion that, if they are to meet the hopes placed in them, these policies call for a prior adjustment of the structures for the financing, conduct and utilisation of scientific activity. These countries therefore find themselves "in search of a policy" of structural reform, for which purpose it is less urgent to formulate objectives than to adjust institutional means[4].

On the whole, the situation is very different for the five countries whose research policies are reviewed here.

It is true that, like France and the United Kingdom, Belgium, for example, seems particularly anxious to renovate its academic and industrial structures. This desire is, however, never based on the launching of big technological programmes. It is a long term effort. Belgian economic strategy seems to be essentially linked with the need to adapt a relatively antiquated industrial structure, rather than a desire to stimulate an aptitude for innovation as such. The special circumstances of this strategy mean that it spreads far beyond the confines of research policy, which is only one element in it.

For the other four countries, the economic infrastructure of research is not at issue and the question of favourable structures for innovation cannot arise in the same way as in France or the United Kingdom. The question for these four countries is not so much to reach a higher level of performance as to stand up to increasingly keen international competition. There is also a question— which concerns Belgium as much as the other four countries— of going beyond the purely economic context and taking account of the new social and cultural objectives concerned with preserving or improving the natural or artificial environments of human activity: the effects of industrial development may, in fact, be felt with special force in these countries, because of their smaller social and geographic dimensions.

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[3] Cf. *Science, Growth and Society: A New Perspective*, OECD, Paris, 1971.

[4] See Volume I, Part I.

In practice, world industrial competition is developing on an ever wider front and, apparently, at an ever growing speed. In the old days relatively narrow specialisations allowed relatively small firms to dodge competition by means of highly specialised and technologically advanced products. With the expansion of scientific and technological efforts in different countries, these "technological niches" became harder to find and, if they were to be lastingly held, called for substantial capital investment. A similar trend is taking shape in the advanced research sector; countries with relatively modest resources find themselves more and more directly faced with the need to concentrate their efforts in certain fields. The difficulty is obviously to choose effectively.

Similarly, it is not enough to saddle science vaguely with all or part of the responsibility for human progress; we must go further and specify the specific technological objectives which should be set, with their order of urgency and scale of priorities. Do the countries reviewed, however, possess the necessary institutions and mechanisms to enable them to make difficult choices for which they have not been prepared by the very liberal climate which has presided over their past successes ?

In attempting, therefore, to elucidate the elements of the problem now facing these countries, we shall try to isolate those success factors which at present appear to hamper the definition of objectives which are necessary if the collective interest in the direction taken by science and technology is to be taken fully into account. We shall then enquire into the international repercussions of such national experiences and their value as examples.

Chapter I

INNOVATION AND TRADITION IN THE SERVICE OF ECONOMIC PROGRESS

National successes such as the ability of each of the five countries reviewed to ensure its population of a standard of living among the highest in the world, the quality of public utility services and the prosperity and drive of so many firms with a world outlook have been sufficiently frequently cited and described in numerous studies to make it unnecessary to dwell on them here[1]. These successes are not of the same magnitude or the same character today in all the five countries, and their international implications, for instance, vary in content and scope. The fact nevertheless remains that, on the whole, the past and present success achieved by the most dynamic enterprises in these countries is based on the creative exploitation of the most advanced technologies.

It is true that the level of this exploitation is not unform, and significant differences bear witness to the diversity of economic histories; mobilised earlier than in other countries, but in favour of branches of industry whose growth is now slowing down, Belgian innovation potential, for example, has to cope with problems of conversion which countries with a more recent industrial development still for a time partially escape[2]. On the whole, however, the ability to take advantage, at a decisive moment for industrial development, of the technological breakthroughs assured by national or foreign research has recently been or still is, characteristic of the drive of the economies under review.

The organisation of the research systems in these countries is therefore very important for the light it throws on the way in which scientific and technological progress sustains economic progress. In spite of limited resources, it has been possible to acquire the flexibility needed to keep up with the international scientific and technological evolution only by virtue of social and political factors allowing a high degree of decentralisation which favours the economic aims of technological progress, and ensures that it has a pragmatic and innovating context.

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[1] See, in particular, in the OECD series *Reviews of National Science Policy: Belgium* (1966), *Norway* (1970), *Netherlands* (1972), *Sweden* (1963), *Switzerland* (1971).

[2] The difficulties of the Swiss watch and clock industry could, for example, be compared with those of certain Belgian engineering firms: in both cases a geographical and technological shift of competition decreases the advantage of established industrial capability based on a "capital of innovations". These transformations bear witness to the strength of the trends which necessitate the more active government policy discussed in Part II.

1. The original features of the national approaches

The historians of the relations between science and the State in industrial society draw their examples mainly from the experience of the United Kingdom, France, Germany, the United States and the USSR, since these countries have all at one time or another played a decisive role in speeding up scientific and technological progress and inventing institutions favourable to research.

It should not, however, be inferred from this that countries with less ample resources are doomed to imitation or demarcation. These countries cannot in fact, even though they play a somewhat more subdued part on the international scientific scene, thereby avoid equipping themselves with the scientific and technological resources which meet their specific needs and which harmonise with their traditional political, economic, social and cultural structures. Thus the research policies of the five countries reviewed cannot be regarded simply as the transposition of the policies and institutional formulas of other countries; their originality is, on the contrary, very marked by the fact that the impact of governmental initiatives is, in general, more diffuse, and the spirit of individual entrepreneurship better able to assert itself. Naturally, these specific characters do not rule out resemblances, for example, between bodies with similar functions in several countries; the effectiveness of research has in fact its own imperatives to which local traditions must sometimes yield.

a) *The impact of governmental initiatives*

In any event, the pure and simple transfer to any of the five countries of methods or institutions conceived elsewhere seems impossible; for these methods and institutions seem to take on a new colouring and to yield very different results as soon as they are applied to smaller communities in which all those concerned can, where appropriate, be associated with activities which affect them. Two significant examples of this can be found in the compilation of statistics and the programming of research.

All OECD Member countries have been trying for many years to improve their knowledge of the national scientific and technological potential and to compile the most precise possible statistics on research and development. In countries with highly specialised administrative institutions, these statistical efforts— unless they lead to reforms by way of legislation or regulation— have little influence over the bodies whose activities they seek to analyse.

In countries with more modest government machinery, on the other hand, the administrative mechanisms are more sensitive to the attentions of the "decision-makers"; the questionnaires addressed to the different institutions can therefore be regarded as veritable instructions calling for a reorganisation of management procedures so as to bring out the required results. In such a case, therefore, the influence and use of statistical results becomes much more significant. This influence is all the greater where, as in Belgium and Norway, the quality of the results is exceptionally high.

Belgium, for example, which set about the inventory of its scientific and technological resources some years ago, before most other Member countries, has succeeded in giving this statistical exercise a strategic, and even a policy, content; the timetable and different phases of the inquiry were in fact planned by the science policy-makers with a view to encouraging the bodies questioned to acquire a greater self-knowledge and to inquire into the gaps in their knowledge and their forecasting. In this way a process was set off, particularly in the university institutions which had not yet developed means of self-analysis and of drawing up rational and coherent budgets. Some years later, a Belgian University, the French language University of Louvain, is often cited as an example of the most advanced application in Europe of modern management methods to university activity.

In Switzerland, a very different approach has been adopted towards the census of industrial research and development; the recognition of the centralising influence which might be exercised by a statistical inventory compiled by the central government led to the responsibility for the inquiry being assigned in 1966 to a private business association, the *Vorort* of the Union Suisse du Commerce et de l'Industrie. This Federation, the "summit" body of Swiss employers, set up a special organ to carry out this task, the Commission for Science and Research, whose mission is to take part in formulating national science policy.

Thus, the compilation of an inventory of R & D activities had a centralising effect in Belgium, whereas it reinforced decentralisation in Switzerland. Different national social and political peculiarities may therefore mean that similar procedures have diametrically opposed results. In both cases, however, these examples illustrate the influence which may be exercised in some countries by actions which are elsewhere regarded as neutral. This metamorphosis is all the more manifest when a new dimension is introduced by the juxtaposition of objectives habitually regarded as distinct.

The main objectives of the long term programming effort undertaken by the Norwegian Council for Scientific and Industrial Research (NTNF), for example, are to resist the natural tendency towards obsolescence in government research institutes, to revive the interest of industrialists in the possibilities afforded by science by informing them of the latest progress and to lay down the broad lines of a medium-term national industrial strategy which takes account of technological evolution.

The main task of NTNF is to stimulate and support the country's applied research effort, either by developing its own installations and programmes, or by aiding research of industrial value by the contribution of ideas, skills or grants. A body such as the NTNF is, however, in danger as shown by the experience of several countries, of accumulating over the years a specialised potential which weighs it down and limits its flexibility by making it lose sight of the need to contribute to the renovation of economic activity by initiating the exploration of new fields. This risk is all the more serious when international trade plays a leading part in the country's economy and the trend of world technology must be closely followed and even anticipated.

The NTNF has proved its ability to react against these risks of obsolescence and to preserve its capacity to convert and renew by embarking since 1970 on long term programming which has enabled it to keep in close touch with all tendencies of scientific and economic life. With this object, the range of the Council's activity has been reviewed by a score of specialised commissions which have surveyed the activity of NTNF and Norwegian firms in the light of the general trend of world technology in each field of research (horizontal commission) or of the prospects of each sector of Norwegian industry (vertical commissions).

Programming proper is approached in several stages: ten-year forecast analysis— analysis of national objectives and the means required to achieve them— drawing up the four-year programme— allocating tasks. It bears witness, in any event, to a more sustained and far-reaching effort than in any other Member country, to take into account, when formulating enterprise strategy, the needs and possibilities afforded by research and development, and when setting the objectives of a government agency, the general and specific concerns of national industry. This result could not have been contemplated had it not been possible to ensure without hierarchical "blockages" continuous interaction among the different circles concerned; the success of the programming exercise in applied research therefore appears to depend, in the last analysis, on democratic traditions and on the quality and flexibility of working relations in laboratories, administrations and firms. This effort is followed with great interest by the various research groups who hope to draw from it lessons relevant to their own sectors.[3]

b) *The importance of institutional experimentation*

Each of the five countries can point to a number of original initiatives in organisation of scientific affairs. The flexibility of means and structures indicates that the spirit of institutional experimentation may perhaps more easily lead to concrete achievements in countries where geographic and social differences are smaller, the exchange of information more intense and political, economic and social leaders more accessible.

In any event, none of the five countries has tried to shape its research mechanism to a pre-established model designed to allocate science a precise place in cultural, economic, social and political development. In many respects, the motives and objectives assigned to support for scientific activity are hardly expressly formulated by those responsible. One basic proposition is accepted; scientific development is necessary to the normal development of society. This proposition justifies a relatively modest, but steadily growing, financing of research.

And yet, in spite of this basic pragmatism which does not embarrass itself with theories, the five countries clearly afford the experience of their own pattern of organisation and execution of scientific and technological activity. A pattern built up piece by piece, under the pressure of national and international events and constraints, but a pattern whose experiences and successes often seem to assume the value of examples for all countries.

Without any specialised commissions or ministerial departments subject to close control by the top levels of government, the five countries have, for example, equipped themselves with a great many institutions which act as a link between administrative, industrial and scientific circles. Generally originating from the initiative of individuals who have felt the need to meet the requirements of a particular group or sector these bodies enjoy wide autonomy. The wide variety of their form bears witness to the extremely pragmatic approach to the creation of these bodies. Special mention may be made of the Institute for the Encouragement of Research in Industry and Agriculture (IRSIA) in Belgium, the Engineering Research Foundation at the Technical University (SINTEF) in Norway, the Applied Research Organisation (TNO) in the Netherlands, the Industrial Research Community (AFIF) of the Institute of Technology of Zurich in Switzerland and the Microwave Engineering Institute of the Royal College of Technology in Sweden. Obviously the activities of these bodies vary widely, from subsidising industrial research to making special techniques or exceptional facilities available to firms.

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[3] It has been announced that similar sector analysis will be undertaken by the Agricultural Research Council of Norway (NLVF) and by the Norwegian Research Council for Science and the Humanities (NAVF). Furthermore, the Central Committee for Norwegian Research has recently started the preparation of a long-term perspective analysis with a broader scope covering research in the main problem areas of national concern.

In addition, more traditional governmental bodies are often also able to initiate new activities. Thus, nearly twenty years ago an environmental research programme was started in Sweden under the sponsorship of the Ministry of Agriculture, while it was in the Ministry of Health in the Netherlands that parallel concerns were to manifest themselves earliest and most forcibly.

These various developments indicate the flexibility of government authorities which, at the risk of a certain confusion, have a very broad conception of their responsibilities. In Switzerland the evolution of the Delegation for Employment Opportunity[4] which has led it to support applied research projects, emphasizes this tendency which, thanks to the determination of certain leaders, does not shrink from innovation and experiment, even at the cost of going far beyond the limits originally set for its action.

Interventions from outside the science policy "establishment" may also sometimes prove very effective in leading to the introduction of new programmes or bringing out new priorities. It was, for example, the action of certain Swedish trade union leaders which imposed a wider conception of the "environment" in Sweden to include the artificial environment of individual working lives. As a result the authorities were induced to launch a programme of research into the possibilities of improving working conditions. In another sphere, the creation of the Bank of Sweden Tercentenary Fund and its first efforts, thanks to private initiative, speeded up the development of the social sciences and indirectly stimulated the support given them by the Swedish Government.

Such interventions are, moreover, not exceptional and bear witness to the intensity of exchanges between the different social and economic circles. Various attempts have in fact been made to render these contacts more systematic. These experiments have been carried farthest in Sweden where, in particular, a body such as the RIFO is specifically responsible for encouraging exchanges between Parliamentarians and scientists. The Royal Swedish Academy of Engineering Sciences, for its part, stands out as an example to the world by its ability to keep responsible leaders and public opinion in general informed of the major problems raised by modern technology[5].

Thus, in many aspects of the performance of R & D work, especially in ensuring the inter-penetration and renovation of the different sectors of activity, the five countries have tried their own experiments and worked out their own solutions. It will be seen that their character is no less specific in the matter of decision-making.

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[4] *Reviews of National Science Policy. - Switzerland, op. cit.*, pp. 72-74.
[5] See Part IV.

2. The diffusion of responsibilities

The effectiveness of individual imagination and drive in societies which often display profoundly traditionalist characteristics means that a new type of outstanding personality, combining the spirit of enterprise and sagacity with recognised special skills, must be able to emerge and assert itself in positions of responsibility. In the five countries, it is probable that the smaller scale of the setting confers greater influence and moral authority on the personalities who, in the interests of efficiency, have married knowledge with capacity to act. Among the most distinguished we may cite the names of men like Dr. Jacques Spaey in Belgium and Professor Alexander von Muralt in Switzerland, each of whom exerted a decisive influence— though in very different directions— on the development of his country's science policy.

The quality and extent of individual contacts by a given personality naturally facilitates the exercise of an influence which may sometimes be strong enough to carry weight in the formulation of national policy. The intensity of exchanges between all political, economic, social and cultural circles concerned with scientific and technical activity is obviously essential to such a process of formation of research policy "personalities". In this connection, the relatively small size of the scientific and technological communities may play a very favourable part in the emergence of leaders. Conversely, however, institutions that do not attract such individuals may be hampered in their efforts to attain national prominence.

In each of the five countries reviewed, there is a relatively small number of scientists and engineers in each field: most of them know each other and often even maintain continuing friendly relations which give a personal character to professional contacts. It must be stressed, nevertheless, that although these contacts ensure the integration of the scientific milieu, they do not necessarily lead to common scientific undertakings[6].

It is somewhat difficult to support these comments on the relative size of the scientific communities in Member countries by homogeneous and comparable figures. By way of indication, however, Graph 1 shows student enrolments in pure science in all higher education in the five countries reviewed as well as in France, Germany and the United Kingdom. While it must again be stressed that these figures can be used only with caution in view of the wide variation of mechanisms and definitions from one country to another, the difference of scale between the first five countries and the other three is evident. This difference is bound to affect the quality and intensity of relations within the scientific communities which result from a process of severe selection from among an already relatively small total.

Scientific life— and intellectual life in general— therefore develops in the five countries reviewed in a very different context from that described in France, Germany and the United Kingdom. In a small number of schools and universities and then in a small number of laboratories, each

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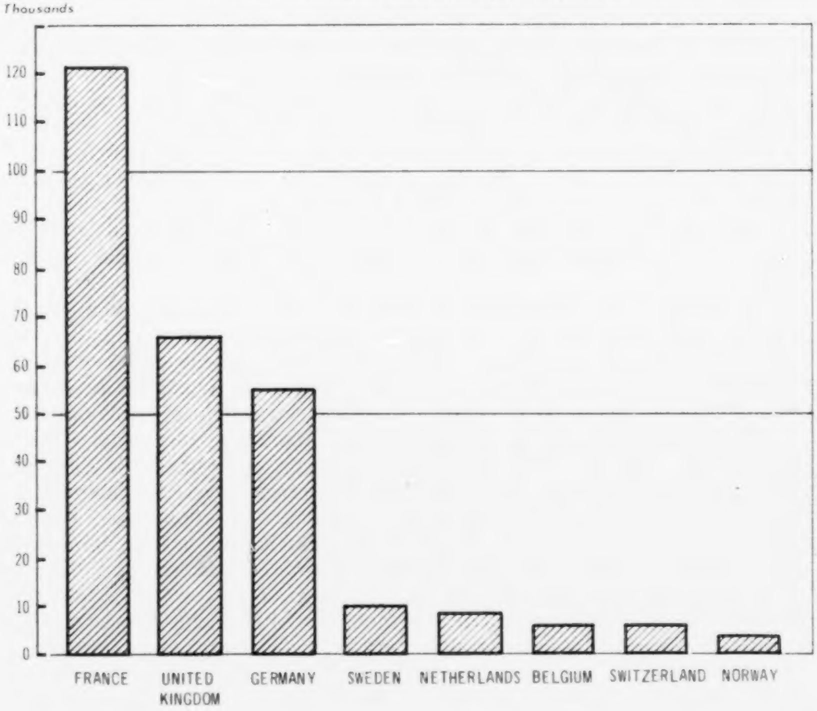
[6] See Part II, Introduction.

Graph 1. ENROLMENTS IN PURE SCIENCE
IN ALL HIGHER EDUCATION, 1965-1966



Source: Development of Higher Education, 1950-1967, OECD, Paris, 1970.

member of the community very soon gets to know most of his colleagues in all disciplines. It is true that these personal contacts do not necessarily lead to co-operation in research, and may be accompanied by subtle and numerous status differences. Contacts, however, do foster the creation of a milieu very homogeneous in its conception of its special features and its professional interests.

This state of affairs is very apparent in the relations between science and politics. As in all Member countries, the five countries reviewed have had to cope with the problems raised by scientific and technological development and have had to associate specialists more and closely with the preparation of administrative and political decisions. This association has all the greater impact when the scientific communities in question are relatively small and each of their members is called upon directly or indirectly to participate in the deliberations of the authorities; if a man is not himself a member of this or that official or unofficial committee, he knows most of its members intimately. In this way the many imperatives or new tendencies of research policy —and especially of finance— are foreshadowed and generally discussed within the scientific community before official decisions are taken or sometimes even envisaged.

This explains the diffusion of responsibilities which is found in nearly all fields; the fact that all its members are familiar with each other gives the scientific community a particular cohesion. To a large extent it becomes a necessity to take everbody's point of view into account. Decisions cannot be taken until the widest consultations have been completed. For this reason, the preparation of decisions usually consists of the search for a consensus. In this context, the use of committees, commissions or councils becomes systematic, to such a point that it has been possible to speak of "government by commissions of study or inquiry". Obviously, this state of affairs does not make easier the development of a governmental science policy.

It is true that commissions of study or inquiry are not unknown in other Member countries, where they sometimes assume a scope going beyond purely technical considerations. Thus, in France, on the formulation of the Economic and Social Development Plan, commissions enable the different interested parties to try to define in common generally acceptable options.

This procedure remains exceptional and, moreover, only rarely meets the hopes placed in it. In the five countries, on the other hand, the constitution of a working party whose members represent divergent interests is the most normal way of arriving at a policy based on consensus. In this way problems of government organisation, the scientific and technological contributions to defence, the co-ordination of ministerial action, and university development have been studied and set on the road towards a solution. When the work of a commission does not result in conclusions acceptable to all those concerned a new working party is usually set up sooner or later... This procedure, as everyone recognises, responds remarkably well to the needs of countries whose social and political traditions are hostile to an over rigid centralism and demand progressive adaptations. However, it may only be effective when available resources grow sufficiently rapidly to prevent internal tensions within the scientific and technological communities.

Even at times of relative prosperity, furthermore, the system has its limitations and is in danger of paralysing the machanism of decision when too stubborn opposition makes it impossible to reach consensus among the prospective partners or when they are too prone to agree on inaction. This kind of situation has led in Belgium to the virtual disregard of the Conseil National de la Politique Scientifique (CNPS) as a science policy making and directing body, in favour of executive bodies which have been led to promote "voluntarist" policy in order to define and promote the accomplishment of the goals of the national science policy. It must be noted, however, that the Conseil National remains the forum for concentration on science policy matters, and retains its advisory role with the government. It is the council, in particular, which has suggested the objective criteria in the field of university policy which have been adopted by the Belgian Government. In this instance, in fact, the desire to gain the agreement of all those interested can be detected in the attempt to finalise administrative procedures based on objective criteria, such as, for example, the number of students for the financing of higher education[7].

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[7] See Part II.

Similarly, in Norway, the financing of research councils by an automatic levy on football pool betting for a long time avoided any budget discussion. The demand for government grants for research, however, has become increasingly pressing, while the Norwegian Research Council for Science and Humanities has not so far been able to suggest to the budget administrators any operational critera for the allocation of resources to institutes. This state of affairs leads certain observers to think that, as in Belgium, the Norwegian authorities may be led to adopt a more active policy, paying less attention to all the wishes of all the different interested parties.

It is indeed true that the widespread recourse to commissions of inquiry and working parties prevailing in the five countries greatly slows down the decision-making process.

Thus, it is not exceptional to find an idea or a project swallowed up in the labyrinth of commissions without a specific decision ever being taken, as seems to have been the case with the proposals put forward in Norway four years ago for the stimulation of educational research. Conversely, in Belgium, an unaccustomed effort of centralisation proved indispensable to the success of the reforms necessary to achieve the objectives set by the Government in the scientific and university sphere. In most cases, however, research policy is still defined by a consensus which is the opposite of any centralising idea and which sometimes, as in Norway, means that the advisory bodies have a tendency to become larger and larger.

It is not surprising, in this context, that the responsibilities of reflection, decision-making and execution are extremely diffuse and tend to respond to events rather than to anticipate them. By facilitating flexible adaptations, however, this highly decentralised system has undoubted advantages.

3. Flexibility or "voluntarism"

Various bodies have been set up in the five countries for the express purpose of financing fundamental research. The Belgian FNRS, the Swiss National Fund, the Netherlands ZWO, the Norwegian Research Council for Science and the Humanitites, and the Swedish research councils represent a fairly varied range of institutional responses on this point.

In view of this diversity of forms of organisation, it is striking to note how similar policies often are. These institutions generally conceive their role as being to respond rather than to initiate. As a general rule financing responds to proposals emanating from scientists, but does not systematically try to encourage certain specific fields, as is done, for example, by the British SRC or the German DFG.

To reinforce existing strong points, to keep abreast of the most modern advances of science by responding to the changing preoccupations of researchers, to avoid strangling the moving reality of scientific development with bureaucratic red tape, all these are the justifications of this policy which induces the authorities responsible for research financing to respond year by year to the stream of proposals put forward in the different disciplines.

No doubt this over-mechanistic picture needs some qualification. The different structures of the scientific communities in the five countries favour the rapid circulation of information, the sharing of concerns and even in some cases the transmission of fashions; the unofficial interest taken by a selection committee in a new field of research is very quickly known and may be enough to encourage proposals.

In some cases, moreover, certain institutions have tried to retain a certain freedom of manœuvre and to take the initiative in stimulating the curiosity of researchers in fields of collective interest: reference has already been made to the very early interest taken by certain countries in environmental problems; other examples are the research on alcoholism and narcotics encouraged in Sweden by the Medical Research Council.

In spite of such initiatives, examples of which are to be found in each country, the most general practice is to modulate the distribution of credits according to the stream of proposals put forward in each discipline. This essentially "responsive" strategy explains, in particular, why, in order to avoid refusals or difficult choices, credits are very frequently spread too thinly, at the risk of not specifically encouraging the best researchers or leading to under-development in certain costly fields which require large teams[8]. These problems, already encountered in France, Germany and the United Kingdom[9] become even more pressing when a narrower national context contributes towards personalising, and therefore inhibiting, all decisions. Thus, one of the Norwegian Research Councils has said: "The central authorities have not yet shown any real interest in how we can increase the quality of our research"[10].

Thus, on the whole, the co-ordination of the research policies of the different government bodies remains mainly technical, aimed above all at limiting the proliferation of parallel efforts and facilitating the exchange of results. This technical co-ordination, moreover, is always very discreet.

Political co-ordination aimed at concentrating or re-allocating resources in fields chosen for their national interest nevertheless remains exceptional. The authorities generally seem to rely upon what might be called the "scientific and industrial complex" to keep the calls on public funds within reasonable limits and to ensure that research of social or industrial importance is not neglected.

The choice of methods and orientations nearly always result from the agreement of the interested parties. There may be some fear that this compulsory reliance on consensus largely favours inaction, as being less disturbing than action and that the tacit agreement which tends to become established in scientific circles ends by circumventing tensions rather than overcoming them. Only political intervention can then impose a solution when exceptional considerations demand it. In this way responsibility for environmental action in Sweden has been concentrated and the Swiss University Conference is trying, not without difficulties, to sponsor a harmonisation of university policies. Similarly, Belgium has adopted national policies for the environment, computers and relations between public utilities and their users.

These examples of voluntarist action remain exceptional. On the whole, and in the five countries, the funding pattern for fundamental research responds to spontaneous orientations rather than organising them or supporting them. In fact, one may be tempted to believe that the close integration of national scientific and technological communities, as well as the intensity of interaction among scientists and engineers lead to the development of a system where decisions very often simply reflect the original intentions of the various parties— after a formal decision-making process.

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[8] See Part II.

[9] See Volume I, *op. cit.*

[10] Norwegian Research Council for Science and the Humanities (NAVF), *Annual Report, 1968.*

This tendency is clearly apparent at the level of each financing agency for which the distribution of credits among disciplines or the creation of new selection committees is determined by the fluctuations of research proposals.

More generally, the same tendency is also manifest in budget discussions; the volume of resources requested by the different agencies which finance fundamental research is never the subject of public debate outside the administration— as happens occasionally in France or the United Kingdom. In fact funding generally grows at a cruising speed which has often reflected the increase in research proposals received by the agency in question. It should be pointed out here that proposal pressure in a smaller country may have specific features associated with the size and integration of the scientific communities. In particular, mediocre, new or deviating proposals may be more actively discouraged before being submitted to the funding bodies who would not obtain from the proposals they are acquainted with an accurate view of the breadth and quality of the national research efforts.

In any case, the budget requests of these agencies are accepted or rejected purely in the light of the general financial situation. Resources allocated to fundamental research generally continue to grow faster than total public expenditure, since the expansion of higher education everywhere involves today a spectacular growth in research projects, while still remaining below the level which would allow the agencies concerned to finance the projects under a policy of specialisation, co-ordination and the promotion of centres of excellence. Thus, the advice of the Netherlands Science Policy Council on the distribution of budget resources among the different institutions has so far generated little impact on the resource allocations. The budget position has not yet allowed the ample general increase in resources allocated to fundamental research which, as the Council advocate, would alone make it possible to introduce significant priorities in the distribution of grants.

In Sweden, the resources allocated to each of the Research Councils grow at approximately the same rate: the Swedish authorities have not decided to give preference to the disciplines coming under one Council rather than another. In practice, this uniform treatment is apparent only and gives an advantage to the institutions responsible for fields in which proposals increase more slowly. At the present time, for example, one Council is able to grant 60 per cent of the funds requested by scientists, while another can manage only 40 per cent. It is not clear to what extent these differences reflect original, basic ones in the allocation of resources to the various councils.

In many cases, the distribution presently continues to be effected according to the Director of a financing agency, "essentially in the light of the balance of power among the interests represented on our Council". This does not mean that the criterion of scientific quality is disregarded, but that within a certain range of quality, the tendency towards dispersion necessarily prevails. For this reason, too, the "decisions" taken by the central authorities may remain ineffective, for the lack or agencies capable of modulating the flow of finance. According to one Government Science Council: "There are no bodies capable of implementing Cabinet decisions on priorities for fundamental research".

This system is not all disadvantages, as sufficiently proved by the vigour, diversity and quality of the research undertaken in the different sectors in the five countries. Quite the reverse, this decentralisation of powers of decision and this diffusion of responsibilities reinforce the autonomy of the different poles of research and their ability to exert direct pressure on the decision-making process. This system, as we have seen, favours individual initiative and allows rapid adaptation to changing circumstances. Its responsiveness is its greatest quality and has so far enabled it rapidly to overcome many unexpected obstacles. But how will it adapt itself in future to the mobilisation of scientific and technological skills in the service of the national objectives which modern states tend to set themselves?

Chapter II

THE LIMITS OF "LAISSER-FAIRE"

The traditional distribution of tasks in the five countries between the government sector, the industrial sector and the university sector has generally excluded or strictly limited the direct intervention of the public authorities in scientific affairs. Governments have, however, tried to meet the needs of industry by actively encouraging the development and the research activities of establishments of higher technological education. In doing this they exercise a notable, through indirect, influence on the scientific environment by intensifying the intellectual and professional influence of engineers and entrepreneurs[1].

The traditional systems of the five countries have, moreover, proved particularly well fitted to back up the industrial efforts of firms with the means and ambition to open a dialogue with the scientific communities; left largely to themselves in the choice of the objects of their curiosity and their orientations, the universities and particularly the technological universities have, in a number of areas, rendered good service to the industrialists who have appealed to them, precisely because of this freedom, which allowed both rapid changes and the assessment of new knowledge produced by the international scientific community.

1. The coherence of traditional structures

The "laisser-faire" which characterised research policy was an essential factor in its economic efficiency. But this scientific liberalism is today partly challenged by the need felt everywhere to orient scientific activity towards exploring areas relevant to the major problems of modern society, or, more generally, along lines which are sufficiently well defined to ensure economic utilisation of resources.

With regard to the major guidelines, the policy of the five countries has, as a whole aimed at limiting the development of national activities in the "heavy technology" sectors allied to defence, nuclear energy and space ventures. It is true that these activities remain relatively important in national R & D budgets, but this relative importance does not bear witness to a deliberate mobilisation of resources to explore a large technological sector, as in France and the United Kingdom. Generally undertaken essentially in the context of national industrial strategy, sometimes originating in the determination to play a full part in co-operative European undertakings, these activities are often very concentrated and always very specific. Thus,

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[1] See Part IV.

Belgium has up to now launched two national R & D programmes: the one in the environmental field, the other in order to promote computer research. A third national programme concerned with the analysis of collective social inspirations and their satisfaction will soon be undertaken.

The Swedish commitment to neutrality has led that country to seek to be as autonomous as possible in the military sphere and therefore to develop the greatest part of its armaments[2]. In consequence, almost 30 per cent of public R & D expenditure is appropriated to defence. In the other countries the concentration of expenditure in the military, nuclear and space sectors is much less marked.

These activities represent incursions into fields which can be systematically explored only by countries resolved to mobilise and concentrate sufficiently substantial resources. There can be no question of competing with these countries in all fields; the nuclear or space research conducted by the countries reviewed enables them above all to concentrate their resources on specific points, following one or more lines apparently consistent with internationally valid specialisation. Above all, this research ensures that each country makes its presence felt, by virtue, where appropriate, of international co-operation, in fields which are evolving fast and where it hopes ultimately to be in a position to import progress.

A veritable mission of information and exploration is therefore assigned to research in these fields; it must be the road which gives the country the opportunity to participate with other nations in the international effort of production of new knowledge and technologies in highly expensive fields. The pursuit of economic progress is a main motive for this attitude, designed to avoid the appearance of shortcoming in any given field which would prevent the country in question from taking advantage of the results of world scientific and technological research.

Following this line of thought, fundamental research inevitably enjoys a relatively privileged position; it has, in effect, the task of training scientists and engineers capable of benefiting from foreign technologies and of maintaining the quality of efforts in the fields where the country excels; it also has the task of ensuring, in all fields, the link between the national society and economy and the main streams of international scientific life. On the twofold plane of structures and objectives, it therefore seems particularly difficult, in this outline, to distinguish between higher education and research.

Except for some mostly recent programmes, to which we shall have occasion to revert, fundamental research is mainly financed through the medium of higher education budgets— under "general overheads"— or by specialised institutions which judge mainly by the "scientific merit" of proposals and not by their timeliness or political urgency.

It is therefore hardly surprising that the five governments have tried to adapt public financing procedures to the special criteria and ethics of the scientific community which demand that the judgment of peers shall predominate in the selection of candidates for governments grants. In small communities, however, it is difficult to be certain that all judgments are objective and free from any favourable or unfavourable prejudice resulting from familiarity between the applicants and their judges.

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[2] Cf. Ingemar W. H. Dörfer, *System 37 Viggen: Arms, Technology and the Domestication of Glory* (MS.)

But, it was nevertheless asked who was better able than scientists themselves to identify the new fields in which research was likely to yield new result and, once they were identified, to set to work fast enough to remain in the forefront of extremely keen world competition? For most authorities, the answer in the five countries reviewed, was not in doubt for long. Not wishing to impose on researchers a general design as a guide to their work, the authorities limited themselves to setting budget and institutional limits within which scientific activity might develop free from government tutelage.

Government science policy was therefore not so much concerned to lay down guidelines and assign projects as to guarantee the existence of a general framework within which the supply of and demand for research could be matched according to the needs of the hour felt by the different protagonists.

To ensure the equilibrium and vigour of university research, regarded as an essential condition of access to scientific and technological knowledge produced throughout the world, without thereby influencing the spontaneous fluctuations of scientific life; to guarantee the development of the traditional and technological universities and, if need be, to come to the aid of private industry when it was tempted to neglect particularly costly and uncertain fields; these, therefore, are the traditional elements of science policy in the five countries. Thus, university development was ensured in Belgium by working out new financing procedures, in Norway by creating a new university at Tromsö, in Sweden by creating new associated universities and in Switzerland by introducing a federal law on the development of the universities and by federalising the Polytechnic School of the University of Lausanne. In all the countries the resources allocated to higher education have progressed very fast.

The same has been largely true of the financing of university research; grants are allocated by institutions such as the National Scientific Research Fund in Belgium, the Research Council for Science and Humanities in Norway, the research councils in Sweden, the ZWO in the Netherlands and the National Fund in Switzerland —institutions whose choice is based primarily on the scientific merits of proposals. Political, economic and social considerations are scarcely taken into account by these institutions; nor are they trying systematically to develop centres of excellence[3].

This anxiety not to impose upon scientific activity has also led the government authorities to respect the autonomy of industrial applied research, an autonomy which is, moreover, jealously guarded by the enterprises themselves. The authorities therefore make every effort to remain neutral and stay in the background, even when their intervention is necessary. In Norway, with the NTNF and in the Netherlands with the TNO, the State limits itself to making available to firms a research body and an experience which can thus be usefully pooled. In Sweden the relations between industry and national defence policy are governed in detail by contracts for research or supplies, while the STU, solely on the basis of their quality, finances research projects submitted to it by enterprises. In Switzerland, where scientific and technological co-operation between Government and firms, very jealous of their independence, is most limited, the Conferedation has nevertheless taken over the greater part of the nuclear research started by industry[4].

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[3] See Part II.

All these examples indicate a predominant orientation of industrial research policy. National programmes such as the computer development plan in Belgium remain exceptional, and distinguish this country from the four others. As a general rule there is no question of influencing industrial activity but merely of giving it the support of the authorities where appropriate.

Thus, in most fields it seems to be the fundamental principle of government policies to leave to scientists and engineers themselves the decisive responsibility of identifying and seizing new opportunities. In this perspective, charateristics which elsewhere would be defects here become virtues, thanks to the entrepreneurship of institutions and individuals. For example, the tendency to react to events rather than bringing them about and to spread responsibilities as widely as possible might lead, in some societies, to confusion and paralysis. In the countries reviewed, on the contrary, these tendencies ensure the necessary continuity to keep national problems constantly in touch with the possibilities offered by world scientific and technological progress. It remains, however, that new circumstances tend presently to lead to a reduction of these advantages while increasing the influence of the shortcomings of the system.

2. The new international challenge

Limiting oneself to guaranteeing the means might, indeed, result in encouraging the expression of individualism rather than concerted efforts. In particular, this policy undoubtedly involved the risk of fragmentation of scientific activities, parochialism and the tendency to "fundamentalise" work, resulting in more and more esoteric coteries, further and further removed from national concerns; the absence of permanent stimulus originating from political circles might well justify fears of this kind of result in institutional systems which encourage the tendency to introversion.

And yet, the intensity of interactions between those nationally or locally responsible for the different sectors, has, on the whole, stimulated the exchange of information and of new ideas. The capacity for co-operation between sectors which often marks most of the countries reviewed may have led to a permanent exchange of experience between the different sectors and may have made more concrete experiments in co-operation possible in appropriate cases.

This quality of interest in other national scientific activities is today still not found equally in all fields; in the university world the technological disciplines seem readiest to co-operate with firms. Conversely, not all firms display the same openness. Thus, in Belgium, where industrial structures are more traditional, exchanges between the university and industry seem less frequent than in Switzerland.

There differences may perhaps reflect time differences in the historical development of national industries, a country such as Belgium being faced today with problems of conversion and adaptation which may be encountered by other governments tomorrow. In so far as they are less spontaneous, contacts between sectors are nevertheless being more and more systematically encouraged by the Belgian authorities who envisage increasing the number of research programmes mobilising all scientific and technological skills.

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[4] See Part IV.

In countries whose scientific and technological communities are still relatively small, however, the intensity of exchanges between the different sectors would not be enough to ensure the regular renewal of ideas and methods unless such exchanges assumed an international dimension; the consumers of knowledge are often firms with their eyes on international markets and very well informed about the needs and possibilities of their branches; researchers have nearly all acquired part of their training abroad and try to keep up their contacts with the most prestigious centres of international scientific activity.

Openness to the world has, in fact, played an essential role in preserving national scientific communities from introversion; the criterion of scientific merit mainly adopted by governments for the financing of research as a whole could, in effect, be meaningful only so far as that research was close enough to international scientific life to render a good account of itself and to be in a position to explore in good time the new possibilities of application which opened up.

Except for a few fields traditionally regarded as part of the national cultural capital— such as astronomy in the Netherlands, for example— or research sectors of economic interest in which a national specialisation has emerged, none of the five countries seems to be looking systematically for scientific leadership. The main desire seems to be to pursue a policy of preserving or acquiring a favourable position in world scientific and technological competition. The outside contacts of national scientific communities are therefore of decisive importance.

The genuineness of these contacts is all the more striking everywhere since they are the result of spontaneous interest on the part of the researchers themselves rather than deliberately organised by the authorities. Thus, in Norway, the Netherlands, Sweden and Switzerland, it is considered essential not only for every reputable academic to spend one or more periods in the recognised international centre or centres of excellence in his field, but also for every reputable university to take a substantial proportion of foreign researchers into its laboratories. A great many public and private bodies try to encourage these exchanges by often very generous grants and fellowships.

The importance of this international outlook of the scientific communities in the five countries reviewed must not be under-estimated; it provides a twofold incentive and tends to encourage both the quality and the diversity of research work.

No doubt the quality of the work is not uniformly high, although each country has at least one higher education and research institution of international standing. Nevertheless, the desire of the national authorities and of the different establishments and individuals to keep up the most sustained possible international contacts and, especially in the Netherland and Switzerland, to attract distinguished foreign researchers largely explains the relatively high average quality of the work.

The diversification of efforts is another result of the close ties formed with foreign scientific communities.

It is in the light of the major trends and new currents manifest in the world scientific community that the research topics of scientists in the five countries are most frequently selected: one researcher will bring back from a stay abroad an idea for the topic of his future work, another will decide in the light of new information gathered at an international conference and a third will choose in the light of the new trends of world research in his field the subjects he suggests to his best students so that they can make a fruitful stay in the best foreign laboratories and subsequently acquire an international reputation.

This process has long been regarded as perfectly natural and capable of general adoption under a system which made researchers responsible for determining the broad lines of their efforts in the light of the "hot spots" of contemporary science.

Today, however, this kind of behaviour is partially challenged by some observers, who criticise it, in particular, as leading to an exaggerated and growing dispersal of effort; more and more researchers are taking part in international scientific activity, which is thereby being deployed on an ever widening front. In search of originality and anxious to identify themselves with new fields in which they think it possible to make rapid progress without encroaching on the work of others, researchers, too, tend to disperse themselves over an increasingly vast front.

This incitement to dispersal would be bound to grow stronger if the disproportion in research efforts between the five countries and the rest of the world also increased substantially. It is nevertheless difficult to measure this gap in the absence of really complete and comparable data showing the relations between advanced research efforts in the different countries. Research budgets, in particular, hardly point to any general conclusions on this subject.

Nevertheless the work done by Derek de Solla Price on international scientific publications, gives an interesting picture of the relative importance of research in the countries reviewed. It is true that these data— which are influenced in each country by very specific linguistic, cultural, social, institutional and political circumstances— cannot be interpreted as a faithful reflection of the volume and level of each country's scientific activity. They nevertheless provide useful elements of appreciation on the contribution of research efforts in the countries in question to international scientific life.

Thus, if one takes the number of scientists in relation to population, the five countries seem to have a much higher research potential than some other countries which nevertheless outrank them in terms of Gross National Product (Table 1).

The economic and scientific "weight" of each of the five countries can be compared by looking at the share of each of them, first, in world GNP, and then in the world population of scientific authors. Three countries then stand out as exercising a scientific influence far in excess of their economic dimensions.

Switzerland has made a very considerable effort, since, with 0.67 per cent of world GNP, it claims 1.35 per cent of authors. Sweden, with 1.05 per cent of world GNP has nevertheless succeeded in providing 1.28 per cent of authors, and the Netherlands, with 0.99 per cent of world GNP in providing 1.08 per cent.

Norway, for its part, has the same relative influence in the scientific sphere as in the economic sphere. Only Belgium is more active economically than scientifically, with 0.84 per cent of world GNP and only 0.73 per cent of authors.

This state of affairs is, however, likely to change drastically in the next few years. The experience of the last twenty years in fact indicates that the scientific growth of the more advanced countries is decelarating appreciably, while other countries are tending to increase the proportion of their resources allocated to R & D. It may therefore be wondered whether the world scientific "weight" of the small highly industrialised countries has not now reached a peak, implying that improvements can only be gained from improved organisation; that is, at least in part, more centralization, better management and less "laisser-faire".

Table 1. **Scientific Authors of the Five Countries**

Country	GNP		Scientific authors		
			Per 10 m Population	Number of authors	
	World rank	% World wealth	World rank	World rank	% World authors
Switzerland	19	0.67	2	11	1.35
Sweden	15	1.05	6	13	1.28
Norway	31	0.37	10	22	0.37
Netherlands........	16	0.99	14	14	1.08
Belgium	18	0.84	16	18	0.73

Source : Derek J. de Solla Price, *Measuring the Size of Science*, delivered to the Israel Academy of Sciences and Humanities, 11 February 1969.

Many observers therefore ask whether the five countries are not now in the process of crossing a threshold of quality as a result of the world increase in resources allocated to research. Does not the autonomy of decision of scientists in the countries reviewed lead to a growing atomisation of efforts in the light of the number of different lines suggested by world research? Does not the relative limitation of available resources, moreover, tend to make the work done more and more theoretical in fields where the same powerful instruments are not available as those with which some countries have equipped themselves?

Without undue weight being attached to this last argument, which might result in sacrificing reflection to technique, mention must be made of the anxiety felt by political, economic and social leaders who fear the *de facto* institution of an international division of labour leaving the universities of the less richly endowed countries responsible for the most abstract research, determined in the light of world scientific vogues rather than of the problems and needs of the national community.

The lack of organisation and the guaranteed autonomy of the different parties to the national scientific efforts of the countries reviewed have for a long time been the mainsprings of systems founded on the ability of economic and social sectors to seize the opportunities offered by scientific knowledge generated and, above all, transmitted, on the sole responsibility of scientists. The international scientific evolution, however, has increased the mass of information available and has widened the range of possibilities in such proportions that they seem to demand a detailed redefinition of the structures and objectives of science policies in the countries reviewed.

3. Concentration and orientation

In so far as the definition of research activities succeeds in taking account of national necessities and of the relatively limited resources available, a concentration of effort along certain lines of enquiry is unavoidable. In comparing the German, French and British institutional mechanisms[5] with those of the five new countries reviewed, we have been led to the conclusion that the first three countries are better equipped to formulate a science policy, while the last five are on the whole better equipped to absorb and disseminate innovation. The former therefore find themselves today called upon to follow policies mainly designed to set up dynamic and innovative structures. The latter possess the mechanisms favourable to the diffusion of technological progress; they must now equip themselves with the institutional mechanisms which will better enable them to associate national skills with the elaboration and control of that progress. It should be pointed out, however, that Belgium enjoys, to some respects, a situation similar to that of the former three countries: she has developed an effective machinery for the formulation of her science policy, while the economic and industrial structure still remains insufficiently adapted to the absorption and diffusion of innovation.

The task is relatively difficult in countries which have so far largely relied on the competitiveness of their researchers and businessmen. There can, of course, be no question of stifling curiosity, innovation and drive by excessive centralisation which could do no more than assign arbitrary and generally belated directions.

In fact, none of the five countries has attempted any radical reform of the existing system; the national authorities have mainly proceeded piecemeal by trying to set up mechanisms or procedures for strictly limited purposes, superimposed on traditional procedures and objectives without replacing them. Concentration of efforts thus seems to be an additional dimension of national policies rather than a new policy. It is in fact reflected in the coexistence of two very different systems. The first of these systems continues, as in the past, to finance high quality projects formulated by the scientists. The second, on the contrary, is designed to attribute an essential role to government initiative which is expected to encourage researchers to turn towards fields of national interest and to form themselves into adequate teams to deal effectively with the most delicate problems.

This coexistence of different systems is all the more evident, the more manifest is the determination to give the State an active part in the orientation of research.

In Belgium, the Prime Minister assisted by a Secretary of State and more recently in the Netherlands, a Cabinet Minister have been made responsible for formulating and executing national science policy. The opposition to centralisation manifested with varying strength in the other three countries has so far prevented any similar regrouping. On the whole, however, the impact of the activities of the Belgian and Netherlands Ministries on fundamental research, and particularly on university research has remained limited, since financing, on the whole, continues to respond to the general evaluation of higher education or the adjustment of credits in the light of proposals submitted by researchers.

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[5] See Volume I, pp. 43-53.

The possibility of mobilising resources which would not be subject to the normal competition between projects is in any event one of the first considerations of any policy for encouraging special fields of research. In the traditional financing circuits, distribution among men and disciplines on equalitarian principles is the most common practice. The volume of requests and the relatively small growth in resources allocated to research financing institutions scarcely allows, in general, the adoption of any other strategy. The main exceptions are found where the researchers themselves have been able to submit fairly elaborate collective research projects. In the Netherlands, moreover, the ZWO has tried to limit the dispersal of effort by encouraging the development of "research communities"[6].

The initiation of ambitious collective efforts in the field of fundamental research backed by government intentions therefore required the creation of special financing mechanisms. In Belgium "concerted fundamental research actions"[7] have been introduced for this purpose. Their object is temporarily to subsidise fundamental research projects in priority sectors selected as a result of veritable invitations to tender addressed to the universities in concert with them. The appropriations— amounting to BF 150 million in 1971— are included in the Prime Minister's budget and therefore do not prejudice the regular functioning of the National Fund for Scientific Research.

More recently, in the Netherlands, an "appropriation for R & D policy" has been included in the budget of the Ministry for Education and Science to give that Ministry the means of responding to urgent requests to meet unexpected, new, lines of research in the course of the fiscal year. Some observers, however, think that this item might become increasingly a source of finance for launching priority research actions.

This method of financing, which amounts to introducing an exceptional procedure for exceptional cases, is at present under active discussion by the Norwegian, Swiss and Swedish authorities. Among other possibilities, one of those most frequently spoken of is to increase the resources allocated to existing research financing institutions, requiring them to use part of these new appropriations to encourage collective research designed to constitute "strong points" in the different university establishments. Where appropriate, this action might follow the major guidelines laid down by the top level science policy bodies. These possibilities have, however, scarcely gone beyond the discussion stage in the three countries.

In Sweden, the levelling-off in the general growth of resources allocated to R & D makes any new priorities policy difficult at the present moment.

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[6] See Part II.

[7] Under this plan, concerted actions involve the association of the authorities and the universities and not necessarily, as in the French "concerted actions", a co-operative effort between leaders and researchers in the public sector, universities and industry.

In Norway and Switzerland the attention of the authorities has so far centred on questions of financing universities[8] rather than on ways and means of developing university research.

Though preoccupied by the always burning question of financing higher education, the authorities of the five countries have contributed to setting up procedures and institutions which were bound to influence the course of research by facilitating the possible redistribution of tasks. Thus, in Norway, the four-yearly planning of university development, which has just been undertaken, should lead to a national strategy for university development designed to identify more clearly the role and limits of each institution. It was in any event with this in view that the Norwegian authorities planned with particular care the creation of the University of Tromsö. Forming part of a regional development effort, the creation of this new university was also designed to meet the needs of the national university system and to orient the new institution in the direction of useful and effective specialisation.

In Switzerland another effort has been undertaken to introduce into the universities a certain co-ordination and consequently a certain specialisation; this was one of the tasks assigned to the University Conference in 1968[9]. The Conference, however, made little progress along these lines, no doubt as a result of keen Cantonal or regional misgivings. Furthermore, its competence extended only to the university sector proper and it could not try to harmonise the activities of this sector with those of the Institutes of Technology.

It nevertheless seems that the new Constitutional Articles on education and research are likely to make radical changes in the conditions of university development in the next few years.

With regard to research, efforts of orientation and concentration remain relatively fragmentary in the five countries. The scanty resources available or the transitional phase through which the universities are passing, may partly explain this state of affairs. Furthermore, the choice of orientations and priorities in the field of fundamental research have not always been made clearly explicit.

This task was, moreover, not easy for these advisory bodies which represented the national scientific communities in their relations with the authorities and which were therefore by no means anxious to discuss questions which might create a real political split between representatives of allied institutions or disciplines. Furthermore, most of these bodies came under Ministries of Education and were in no position to know the different problems and needs of other sectors. Thus, either because of their membership or because of their terms of reference these Councils could not play the same role, for example, as that of the *Wissenschaftsrat* in Germany[10].

In Belgium and in Sweden, these institutions have to some extent been thrust into the background. In the Netherlands and in Norway, the Science Policy Councils nevertheless succeeded in acquiring some influence in the budget process. In Switzerland, moreover, the Federal structures and the complexity of the relations between the Cantons and the Confederation have conferred special eminence on the Swiss Science Council.

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[8] Swtizerland has, however, undertaken an inventory of urgent research problems which could lead to the development of new funding mechanisms. See below, Annex I.

[9] See *Reviews of National Science Policy - Switzerland, op. cit.*, pp. 140-142.

[10] See *Reviews of National Science Policy - United Kingdom/Germany*, OECD, Paris, 1967, pp. 38-39.

Where the advisory bodies have been effaced, however, this has generally contributed to reinforcing the central authorities, who have had to assume the necessary competence to deal with new problems connected with the development of science and technology. In some countries, such as Sweden, executive responsibilities have been shared between the Ministries of Education & Industry. The Prime Minister & the Secretary of State for Science Policy & Programming in Belgium and the Minister without Portfolio in charge of science policy in the Netherlands are, on the contrary, responsible for planning all government activities in this field.

Belgium and Switzerland are the two countries which have tried to select research priorities most systematically. Belgian experience is longer and already goes back some years while the Swiss attempt is quite recent and has not yet resulted in precise government directives. Furthermore, the institutional differences noted above are very largely reflected in the procedures chosen to determine the broad lines of research policy.

The Belgian approach results from a government decision specifying the ways and means of selecting the concerted fundamental research actions referred to above. The projects proposed for the financial year 1971 were selected on the basis of the following criteria:

a) projects in certain sectors or scientific disciplines are at present of special value for the future of science or because of their contribution towards solving certain major social problems;

b) research in these priority sectors generally calls for sufficiently large teams with exceptional scientific skills; the size, budget and existing equipment of these research teams gives an indication of the size of laboratories while the reputation of the promoters is some measure of the scientific value of the research projects to be supported; publications, both in Belgium and abroad, and references to these publications in high grade international scientific periodicals constitute objective criteria of assessment in this respect;

c) research of this kind also requires exceptional financial resources for a limited period so as to enable selected research centres to attain the size needed to carry out research of this kind, where the ordinary resources of host establishments or parallel financing credits are insufficient;

d) in the light of the objectives of Government science policy and in scientific disciplines deemed to be part of the most advanced sectors, universities and scientific research establishments submitted fundamental research projects to the Minister for Science Policy and Programming;

- — these projects will be carried out by research centres coming under the establishments concerned, within the limits of their policy for scientific development;
- — no duplication has been found between the projects selected or between those projects and projects financed from other sources; in some cases the advice of foreign experts has been taken on this point;

- State intervention is limited to giving the initial impetus and in principle amounts to 50 per cent of the true costs; it cannot in any circumstances exceed 80 per cent of the cost; the proportion not covered by the State grant is borne by the host establishment.

The Swiss Science Council, for its part, being anxious, like the Belgian authorities, to take account both of the purely scientific interest of projects, their chances of success and their possible economic and social impact, has adopted an approach by progressive stages based on the participation of the interested parties themselves in working out the major orientations. For this purpose it has since 1970 carried out a thorough inquiry in all public and private quarters.

In the course of the inquiry made during the summer of 1970, more than 1,300 representatives of science, administration and the economy were consulted and indicated more than 2,200 "research needs" in 38 disciplines. Reports on the processing of these replies were prepared, mainly with the permanent co-operation of about 40 young researchers in all disciplines. These process reports were themselves submitted to 180 scientific experts (mostly academic) who were asked to call attention to any gaps, and to classify in order of priority, especially in the light of scientific criteria, the research needs disclosed by the inquiry and to propose practical measures of encouragement. In parallel, another group of experts was asked to assess the economic value of the proposals. The establishment of the final synthesis is the responsibility of the Science Council itself.

The publication of the results and recommendations is scheduled for Spring 1973. A detailed analysis of the procedure followed will be found in the Annex.

The object of the inquiry is to draw up an inventory of "urgent research needs", that is to say, the fields in which urgent measures are necessary, which might range from simple financing to a radical reform of the research organisation of a given institution. Among the categories adopted for processing the inquiry, the following may be noted in particular:

- research needs rendered urgent by external circumstances;
- research needs in general and partial fields of science which seem to be "under-developed";
- problems of research infrastructure and organisation;
- specific research problems.

The Science Council regards this inventory as a first stage in a process which should become continuous. It is in fact planned that on the completion of the present studies "the results obtained will serve as a starting point for working out medium and long term research policy prospects". In future, recourse to scientists and the users of research should become systematic in laying down the broad lines of research policy. The Council considers, in particular, that any orientations it may propose should not lead necessarily to the creation of new research institutes, but to co-ordinating the work of researchers attached to the various institutions, a co-ordination which might be inspired by the methods of the ZWO in the Netherlands. This "mobilisation on the spot" in any event implies, at national level, working out a research strategy which cannot be evolutionary unless it is systematically based on the opinions of the interested parties.

The originality of the experiment thus tried by the Swiss authorities is undoubted in the light of the desire to consult, as widely as possible, all circles interested in research, while leaving the authorities with decisive responsibility for determining objectives.

How far can the public authorities determine the "strong points" of national research without, sooner or later, bringing it under administrative restraints which will hamper its development? How far, moreover, is it possible to associate scientific and technological circles in the formulation of research policy objectives without the danger of consolidating vested positions rather than breaking new ground?

Each in its own way, Belgium and Switzerland have tried to solve the difficult problem of concentrating the resources allocated to research, a concentration rendered indispensable by the limited means available and by the desire to preserve the originality and dynamism of national efforts. In spite of the marked differences between the procedures adopted, neither country has sought to challenge or overthrow the traditional system of organising and orienting national scientific activity; the main aim is to reinforce research centres which are already active, which have given proof of a certain value and which are capable of making profitable use of supplementary resources or institutional improvements to attain a genuinely international standard of quality.

These policies are designed to avoid an excessive fragmentation of efforts and to promote orientations of national value without prejudice to the capacity of the scientific and technological communities for adaptation and change, a capacity which is still largely dependent on traditional modes of organisation.

Annex

DETERMINATION OF URGENT RESEARCH NEEDS[1]

1. Object

In arranging for this inquiry, the Science Council started from the observation that certain scientific services essential to the development of science, society and the economy were not being performed, or were not sufficiently performed in Switzerland. The Science Council feels in duty bound to identify the fields of this kind in the whole of the vast range of scientific work, and on the basis of the results of its inquiry it will recommend precise and urgent measures to encourage certain fields of science. In this first attempt the Science Council deliberately confines itself to determining *urgent* research needs. The results obtained will serve as a starting point for medium and long term research policy forecasting. This work will be started immediately on the completion of the present studies.

2. Inquiry and first processing

The inquiry made among interested circles in July-August, 1970, met with an encouraging success. No fewer than 1,300 representatives of the sectors consulted in science, the administration and the economy indicated, either through questionnaires or by letter, more than 2,200 research needs in 38 disciplines.

Contrary to a widely held opinion, the questionnaires were not constructed with a view to quantitative processing. The questions put left a wide margin for the presentation of ideas and reasons for future developments; they served to collect opinions, suggestions and proposals whose validity had to be tested by a further process of evaluation. As a purely qualitative processing was planned from the outset, it was not necessary to circulate the questionnaires according to the scientific rules of opinion surveys. The aim was to ensure the co-operation of individuals and institutions interested in research policy

We started with the idea that recipients of the questionnaire would be able to identify research needs with a certain uniformity from the point of view of branches of research. This proved to be only partly correct; the degree of abstractness of the different answers varied greatly. Some related simply to an isolated research project while others asked for encouragement of whole fields of science; others again referred to problems of training or research infrastructure, or contented themselves with calling attention to a given problem without specifying the scientific contribution needed. The lack of uniformity in the replies complicated the systemisation of results in the 38 sectors adopted for processing.

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[1] *Source:* Swiss Science Council (unofficial translation by the OECD Secretariat).

Thanks to the contribution of some 40 young scientists from all disciplines, whose co-operation with the Science Council was, in most cases, rendered possible through the Swiss Association of Young Scientists, we had available by the autumn of 1970 a process report in most of the scientific disciplines and in some interdisciplinary fields.

As a general rule these *process reports* were in two parts. The first part was confined do a *summary of research* proposals. In the second part the rapporteurs were asked to assess the research needs in the light of the general context and the criteria applied.

In most fields the material processed proved to be suggestive and varied, but incomplete. In the first place, some institutions had not been reached by the method of distributing questionnaires chosen by the Science Council, in spite of the fact that anyone could obtain a form on request and return it. Secondly, a great many of the institutes, bodies or institutions consulted did not answer.

3. Expert advice on the process reports

In preparing our inquiry we had assumed that the urgent research needs existing in the different scientific fields could be identified relatively easily and quickly. We had hoped that in the different disciplines opinion on the subject of the necessary developments and measures to be taken was already clearly formed and that the first task would be to make contact and exchange views with the groups interested and to harmonise the necessary measures at the national level. These assumptions proved incorrect in almost every field.

The lack of uniformity in the process reports, which differed widely in quality according to the nature of the basic documents, called for meticulous evaluation; it was particularly necessary *to complete the available data* and to establish criteria of judgment. The Science Council had no mechanism available for this purpose which would enable it to form an opinion within each discipline. Only the Swiss National Fund, in an important document, expressed an opinion on priority research needs in all disciplines.

The Science Council deemed it necessary to arrange for discussion of the research needs brought out by the inquiry in groups of active researchers competent in the different disciplines. Towards the end of 1970, therefore, it approached about 180 scientific experts (mainly university teachers) and asked for their opinion on the process reports.

In a note of guidance the Council emphasised that the data contained in the process reports were incomplete, and, furthermore, that part of them reflected existing research activities; it also noted that, particularly when the manner of formulating the problem was out of date or inadequate, it was impossible to express an opinion on research needs without calling upon expert skills in the subject.

It therefore invited the experts to bring out the gaps in the data compiled and to assess and rank in priority, especially on scientific criteria, the research needs indicated by the inquiry and to propose practical measures of encouragement.

In general, the experts expressed their opinions on these three points. A number of aspects among those which proved most interesting in the later discussions made their first appearance in the experts' reports. The essential part of their work of evaluation was to determine the scientific questions to which priority should be assigned and whose scientific study called for urgent measures of encouragement on the part of the State.

Two questions immediately arose in connection with this evaluation. *(a)* How far does a given field occupy *a key position* for the development of knowledge in the relevant discipline or allied disciplines? (*b*) What is the importance of certain research proposals in *meeting the major needs of society?*

In their reports the experts set out their views and the criteria they had applied in drawing up their orders of priority. In doing this, they completed at the same time an important preliminary task in assessing research needs from the point of view of national science policy.

About 150 experts expressed their views in writing in the course of these consultations. Their opinions diverged considerably in certain disciplines, in so far as ideas about priorities themselves differed from one expert to another. For this reason it was necessary, in some instances, after consulting the experts, to arrange for an exchange of views in order to arrive at a synthesis.

4. Drawing up final reports by field of science

In order to determine the orientations at science policy level, the Science Council must be able to rely on orders of priority established as precisely as possible within each field of science. The process reports and the experts' opinions constituted a first basis; it was necessary to go one step further *and collate the opinions of the rapporteurs and the experts in each field of science,* to arrive at a synthesis if possible, and to bring out the results in a final report for each sector.

Thus, the expert views of the different specialists consulted were exchanged within the different groups of experts and discussed at one or more meetings. In nearly all groups it proved possible to reach agreement on priorities within the same field of science. The final sector reports were approved by the experts; they will be published at the same time as the Report of the Science Council.

Since the final discussion in the Science Council on urgent measures of encouragement, with a view to formulating a research policy, must be based on sound knowledge of the situation in the different fields of science and their reciprocal relations, one or more members of the Council or its secretariat were associated with the expert groups in their work of evaluation. The researcher members of the Council, in particular, volunteered for this work, which was often protracted and, in some fields lasted for several months. In many disciplines they themselves had to write the first drafts of the final reports.

It is obvious that the thorough comparison of final reports in different fields of science, necessary for the formulation of a research policy, is possible only if the reports have been drawn up on comparable principles. It was for this reason that we recommended the expert groups to distinguish the following six operations:

1. To designate non-urgent research needs.
2. To fix points of contact with the other fields adopted for processing, and in particular to define major new interdisciplinary fields.
3. To group research needs in comparable units capable of evaluation.
4. To identify aims and criteria.
5. To evaluate and rank in order of priority the research needs grouped according to the aims and criteria defined.
6. To make proposals for practical measures of encouragement.

The *essential problems* in this phase were the final definition of the concept of « *urgency* » and the formulation of appropriate *objectives and criteria* as standards of evaluation.

The definition of « urgency » had already been a source of difficulties in drawing up the questionnaires. We deliberately refrained from an exact and therefore restrictive definition of this concept. If we had confined ourselves to an inquiry into research needs with a time urgency only (for example where there is a danger of information being lost because a subject of research or research equipment is available for a limited time only or because there is some time limit on the use of research results) this would not have met the policy objective set for our inquiry; the task was also to determine the research needs which, for scientific and social reasons were of such importance (for example, the danger of irreparable damage) that they must be met without delay and therefore called for urgent measures to encourage research.

No preliminary work had, however, been done, either at policy level or at research level, which would have made it possible to limit the inquiry to certain categories of problem. Neither was there anyone with the necessary overall view to establish such priorities. We therefore had to determine the research needs regarded as urgent on the widest possible basis.

It was therefore only on the completion of this work that the aims and criteria necessary for evaluation and ranking in priority could be worked out for the different fields of science in the expert groups.

The groups set about this arduous work and tried to give reasons for their choice of priorities and to relate it to the aims and criteria selected, as well as clarifying the decision process in the different disciplines. It became apparent on this occasion that there were no usable methodological instruments yet available to give objective shape to the results of a priority ranking of this kind made partly at the level of research policy. The finalisation of adequate methods for setting priorities in research policies and translating them into concrete measures of encouragement should be a challenge to science in the future.

The procedures chosen by the Science Council, of comparing the largest possible number of opinions has led to well-founded and substantial results. The final reports of the expert groups, which had nearly all been drafted by the end of 1971, provide a conspectus of the research needs existing in all scientific disciplines, which had hitherto been lacking in Switzerland. They contained abundant suggestions addressed not only to scientific bodies but also to higher education establishments and to science itself.

It was nevertheless apparent that the experts could only rarely specify in full detail the concrete measures necessary to satisfy research needs. In many fields the work already started will have to be continued. This is particularly true of the fields of research which are, in our opinion, insufficiently developed and which could therefore be described as «under-developed». In these cases, it has often been necessary to rest content with bringing out the first elements of development to be given concrete form later; special efforts will be needed to put these ideas into practice, from the point of view both of organisation and finance.

5. Evaluation at Science Council level

Whereas, up to this stage of the undertaking, the work of processing and evaluation at the level of the *different fields of science* had been done essentially by specialists in the different disciplines, the task in the last phase was to evaluate overall the fields and problems of research assigned priority in the final reports (horizontal inter-sectoral evaluation).

The fundamental question was how to determine the *value* of the research needs brought out. We originally intended to make a separate evaluation from three different angles, scientific value, economic value and social value. Scientific value was to be assessed by groups of experts in the different disciplines, and economic and social value, on the other hand, by mixed groups.

As indicated by the preceding chapter, scientific value was finally assessed in the expert groups. They considered the scientific value and importance of research proposals in the light of scientific criteria (such as key function), but at the same time they explicitly or implicitly expressed an opinion on social value and, in part, also on economic value. It is impossible to draw a sharp line of demarcation between the three aspects.

Economic value was assessed by a conference of experts called by the Commission for the encouragement of scientific research. It became apparent on this occasion that the economy, too, was faced with difficult problems in determining and evaluating its research needs. It was, however, possible to bring out certain general tendencies; furthermore, the inquiries made by this Commission into the research needs of the textiles and clothing industries and the light machinery and instruments industry were particularly fruitful, since it has been possible to use their results in the present inquiry.

On the other hand it proved impossible to evaluate from a purely social and political angle research undertaken from scientific motives. We thought of setting up working parties which, starting from the most important task of the State (e.g. education, public health, protection of the environment, land use planning, national defence, etc.) would determine the importance of research needs in these fields. The process reports were, of course, also submitted to the authorities, but in many cases they were unable to express an opinion on all the aspects of the research needs brought out. In order to translate these general social and political problems into specific topics of scientific research, or to judge research proposals from the point of view of their importance in solving social and political problems, it is essential to have competence both in the general social and political aspects of these problems and in the methods and possibilities of research in the relevant fields. There are still very few bodies in Switzerland which combine scientific and political competence in this way.

In order to allow interaction between general policy and science policy, we compared the research needs based on social and political motives with the Report of the Federal Council on the broad lines of government policy 1968-1971. (The broad lines for the next legislative period had not yet been laid down.) But this afforded only very slight support for fixing priorities: in the first place, the « broad lines » set no well-defined priorities between the different functions of the State and, secondly, they are laid down at a level from which concrete research policy tasks cannot yet be inferred.

The integration of general policy and science policy will in any event be extremely important in future for setting priorities. This topic is currently under discussion in many other countries and in leading international organisations.

Under its general terms of reference, the Science Council has to consider the research needs of science, society and the economy, in *the overall context.* It is for this reason that the research needs listed in the sectoral reports had to be assessed from the three different aspects in the final evaluation.

The different research needs cannot be judiciously evaluated unless they are comparable with each other; categories therefore had to be found within which classification and priority ranking seemed possible. The Science Council decided to adopt the following *evaluation groups:*

a) research needs rendered urgent by *external circumstances in time;*
b) research needs in general and partial fields of science which seem to be *«under-developed»*;
c) problems of research *infrastructure and organisation;*
d) specific research problems.

Each of these major groups, representing very different problems was further subdivided. The «under-developed» group, for example, was subdivided into:

- disciplines and general fields
  (e.g. computer sciences, documentation, educational research, general systems study, sociology, etc.);
- branches of research and disciplines
  (e.g. biotechnology, clinical virology, legislative science, etc.).

The «research infrastructure» category, on the other hand, covered questions of training, encouragement for the succession of researchers, co-ordination, co-operation and research auxiliaries.

The next stage was to evaluate and rank in priority research needs within the different evaluation groups. The Science Council decided in favour of three *degrees of urgency* to be assigned to the recommendations in the final reports:

a) fields in which research should be encouraged by special measures or means;
b) fields in which research should be developed by restructuration and concentration of means under existing budgets for the encouragement of research;
c) fields which should be developed under the ordinary growth of the resources allocated to research.

It follows from the definition of the three degrees of urgency that the true importance of a field need not necessarily coincide with the degree of priority assigned to it. A field with high social and economic priority (e.g. research on construction) should not be assigned the highest degree of urgency when the desirable research policy measures have, for example, already been initiated (research mandate for the construction of «an integrated model of research on construction»). The assignment of one of the three degrees indicates merely the urgency of the *measures of encouragement* deemed necessary and not an evaluation of the field in itself.

The question whether appropriate urgent measures of encouragement are deemed desirable therefore depends partly on the scientific, economic and social importance attached to the field and partly on the existing state of research and research encouragement in that field.

Research needs are assessed in blocks according to the evaluation groups adopted. Within the «time urgency», « infrastructure» and «isolated problems» groups each of the recommendations made in the final reports was ranked separately in order of priority. In the «under-developed» group, on the other hand, the first step was to assess the field as a whole and only then to assess specific problems. In this way it was possible to assign top urgency to certain problems even when the field as a whole was assigned second or third degree urgency only.

The criteria applied for the purposes of this assessment were as follows:

1. *Intradisciplinary value*

   The importance of the advancement of knowledge in the scientific field and of the possibilities of original research and discoveries in that field.

2. *Interdisciplinary value*

   The importance of developing a discipline from the point or view of its contribution to the development of other fields of science ("key function").

3. *Social value*

   The importance of developing a discipline from the point of view the needs, problems and tasks of society and the State.

4. *Economic value*

   The economic importance of developing a field of research.

Each of the four criteria was given the same importance. Experimental modulations with the same values showed that there was no appreciable change in the order of priority of underdeveloped disciplines if double or treble weight was attached to social value, as might possibly have been envisaged.

At the end of January the evaluation work was on the point of completion at Science Council level. The final report then had to be drafted and the degree of urgency attributed to research needs had to be finally checked in the overall context.

6. Some characteristics of the data assessed

The data assessed in the final phase in order to determine urgent research needs indicate the following general trends:

a) The number of urgent research needs on the ground of time alone is relatively small. They relate mainly to linguistics, history, ethnology and ecology.

b) A series of disciplines and fields of science urgently need development and encouragement in general. They are primarily the education sciences and the social sciences and also the information sciences, particularly documentation and computer sciences. It has been possible to recommend concrete measures of encouragement, from the point of view both of topics and of organisation, in a few of these disciplines only. Further planning work is needed.

c) As well as this, a series of *branches of research* which need sustained encouragement can be identified in particular in certain fields of natural sciences and engineering sciences which, as a whole, seem to be well developed. At the same time a great many specific problems have been identified which still await a solution.

d) One of the main results of the inquiry has been to show the many gaps in the existing research infrastructure. They relate to basic training and postgraduate studies, the encouragement of the succession of researchers, questions of national co-ordination and intradisciplinary and interdisciplinary co-operation as well as gaps in the matter of auxiliary scientific services.

e) At the same time shortcomings have been noted in the matter of the instruments of research policy which must be the foundation of the formulation and execution of research policy measures. In the first place, in nearly all fields of science there is a lack of valid interlocutors with a bent towards forecasting the developments and the skills upon which science policy bodies can rely in formulating their policy for the encouragement of research. Furthermore, in the sphere of research oriented towards practical applications, we do not yet possess any effective and active agencies for the encouragement either of projects launched by science itself or in the fields in which the State should take the initiative in research for the better discharge of its studies. (The rudiments of an agency of encouragement of this kind are to be found in the Commission for the encouragement of scientific research and the Commission for health research.)

7. The use of some results of the determination of urgent research needs

The practical use of some of the results of the determination of urgent research needs has not been held up pending the publication of the full results. It is already possible to point out a whole series of fields in which the results have been put to practical use.

On the basis of the recommendations of the final report on "Medicine", for example, the Science Council decided in favour of participation in the European Training Programme for Research in Brain and Behaviour. On the same basis, the Council has further recommended the constitution of a commission on the compilation and processing of *medical data*. In the light of current initiatives, this recommendation could no longer be deferred.

Some results of the inquiry have already been reflected in the allocation of grants by the Swiss National Fund for 1972.

Reference may also be made to the drawing up of general guidelines for future *research in physics* and of a medium term development plan for sociology. These two initiatives are the direct result of the drafting of the final sector reports.

With a view to future co-operation in establishing the bases of a research policy, preliminary talks have also been held with certain *scientific organisations.* The results of work to date are already being used by the Science Council as a starting point for its advice on certain questions and as a guide for its participation with the Canton representatives on the creation of *new university level institutions.*

It goes without saying that, after the publication of the results the Science Council will systematically study the initiatives which must be taken to give effect to the recommendations, as well as contributing to their achievement. This future activity will be conducted in the context of medium and long term research policy forecasting.

Part II

UNIVERSITY AND RESEARCH IN A TEACHING ORIENTED ENVIRONMENT

by
Gilbert CATY

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INTRODUCTION

The problem raised by the development of university research in the European countries centres on two fairly simple points: a closer link with technology and a readjustment of relations with the teaching function. Volume I has shown how the United Kingdom and France were concentrating their attention on the link with technology which the Federal Republic of Germany seemed to be providing particularly in the technical universities. The need to adapt research to mass education is not so keenly felt, since in the three countries under review the fairly extensive peripheral system affords a satisfactory refuge for the university researchers.

The order of concerns is reversed in the smaller countries, with the exception of Belgium. The links between research and technology seem satisfactory at university level, or meet the needs of industry since, as in Germany, there is a fairly clear-cut binary system, with the technical universities on the one side[1] and the traditional universities, with a greater bent for scientific research, on the other. The traditional universities, on which this survey is concentrated, are at liberty to conduct fairly free advanced research. The scientific mission of the university is all the more marked since, in the five countries under review, the university is at least formally the only sector in which fundamental research is conducted. The so-called peripheral sector[2], so highly developed in France, the Federal Republic and the United Kingdom, is practically non-existent. It follows that the question of the link between teaching and research assumes its full importance and the crisis of adapting research to the mass university acquires a certain magnitude.

The expansion of the student body is very recent and has hit the universities hard. The traditional universities are not getting the means needed to cope with larger numbers. In the first place, government policy may be to attach less importance to the traditional sectors of the universities in order to concentrate their attention and an increasing share of their resources on new forms of post-secondary education which definitely meet a certain need and are exercising a growing attraction for young people. Secondly, governments calculate university needs on the basis of financial, physical and human standards tailored to the needs of teaching. Research Councils provide the financial and human support required to meet the needs of research in the universities. But the increase in their resources is not commensurate with the needs of research and of the diversification of science.

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[1] Technical universities are dealt with in Part IV on "Industry, Science, University"

[2] "Peripheral" refers here to research agencies related symbiotically to the universities. These are the Max-Planck Society in Germany, the CNRS in France and the Research Councils in the United Kingdom. Cf. *The Research System*. Vol. I, Part II.

The result is a fairly severe crisis in university research. The academic is a teacher before he is a researcher and the teaching body is not growing as fast as the student body. Where surveys have been made[3], they show that the time spent by the teaching body on research has diminished in recent years.

The conflict between the teaching function and the research function is apparent not only at the individual level of the teacher-researcher, but even more specifically and profoundly at the level of the university itself in the way it has adopted and "lived" Humboldt's creed of the liaison between teaching and research (both terms of which have, of course, radically changed). The university has not succeeded in overcoming the contradiction between the individual and the institution. The individual is looked upon as a researcher, but the institution is organised as a teaching institution. In the first place, the teacher is a researcher; he is recruited by his peers on the strength of his scientific work; he carves out his career and establishes his authority in and through research, to which he is expected to devote the bulk of his time. On the other hand, as we shall see, not only the principles of financing, but also the internal structure of the traditional universities are built around purely didactic categories— the institution of the Professorial Chair and the straight-line curricula, which, on the whole, have only quite recently been challenged; as yet with uncertain results.

Now, whatever attempts have been made at university innovation, there have been no very obvious results as regards the organisation or financing of research. The universities are marked by a disturbing uniformity and by the absence of originality in relation to the Humboldt model. The multiplication of new universities has only occasionally favoured reflection on the function of the university and the creation of a new model. Similarly, the scarcity of resources which compels choices has only exceptionally and in a roundabout way resulted in an embryonic research policy. The universities have been quite slow to use these restraints to reappraise themselves in the light either of the research function, or of research in its new form of a service to society and in its internal requirements. The reason is that for this purpose it would have been necessary to reappraise the relations of the institution to the individual.

The reforms at present under way only partially tend to break down barriers and partitioning which Research Councils have too often espoused and consolidated. Living on the principles which have ensured their success since they were created after the Second World War, they are made up of specialists and organised on the university pattern. The activities of their committees rarely venture beyond the frontiers of faculties or disciplines.

The paradox of these countries might very well be that the famous intimate knowledge which each member of the scientific community is said to have of his partners is not reflected in science or science policy, and that institutional partitioning, both horizontal and vertical, is more drastic than anywhere else. To the astonishing absence of geographical mobility of students and teachers within the national territory (in contrast with their international mobility) there is added an absence of dialogue between the bodies which have a part to play in research policy, of the universities among themselves, of the universities with the Research Councils, and of the Research Councils with the political authorities.

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[3] "In Norway, Sweden and particularly the Netherlands. Conversations have illustrated this for the five countries concerned."

Until recently these characteristics have been masked by the consensus of the scientific community, the counterpoise offered by the technological universities and the international value of the results achieved in pure research. The lack of human resources, the lack of space and the lack of resources in general, might perpetuate this tendency towards fundamental science and continue to make the university laboratories veritable international hotels for researchers. In view of the international dimension of university research in the countries concerned, the question remains whether the vocation of these countries is to be, at a limited cost, the international sanctuary of pure research or, on the contrary, a logistical base for the penetration of international scientific markets for the benefit of social and industrial needs and the training of their human communities.

Basic University Data

	Number of Universities	Number of Students	*of whom* Science	Technology	Health
Belgium[1] (1970)	9	60,000	21,383		7,729
Norway[2] (1971)	4[6]	32,983	4,726	3,409	2,636
Netherlands[3] (1969-70)	11	96,513	13,585	14,684	12,786
Switzerland[4] (1967-68)	9	34,652	5,133	6,843	6,183
Sweden[5] (1970-71)	9	121,057	14,413	14,099	10,111

[1] Ghent 10,219; Liège 7,743; Catholic Universities of Louvain 11,845; Leuven 12,554; Brussels (Free Universities) 8,691; Brussels (Vrije Universiteit) 1,470; Mons (Polytechnic Faculty, University Centre, Catholic Faculty) 1,226.

[2] Bergen 6,693; Oslo 18,395; Trondheim 5,218; Tromsö 87 (estimated future capacity ca. 3,000); the Agricultural and Veterinary Colleges of Norway 752; Norwegian School of Business Administration and Economics, Bergen 891; other higher educational establishments 947.

[3] Amsterdam 15,608; Amsterdam (Free University) 7,979; Delft 9,848; Eindhoven 3,650; Entschede 1,439; Groningen 9,332; Leyden 10,853; Nimeguen 8,727; Rotterdam Medical Faculty 763; Utrecht 14,512; Wageningen Agricultural University 2,682.

[4] Basle 3,737; Berne 4,464; Fribourg 2,838; Geneva 5,035; Lausanne 3,136; Ecole polytechnique de l'Université de Lausanne 1,143; Neuchâtel 1,191; Zürich 7,408; Ecole polytechnique fédérale 5,700.

[5] Chalmers 4,690; Göteborg 17,804; Karolinska 2,699; Linköping 3,712; Lund 22,453; Stockholm 23,979; Technical University 5,856; Umea 6,558; Uppsala 19,800.

[6] Plus six other institutions of higher learning.

Chapter 1

A UNIFIED OPERATIONAL SYSTEM:
THE UNIVERSITY AS THE RESEARCH PERFORMER

The main characteristic of the countries previously reviewed[1] is, first, a dual financing system, and secondly a dual system of conducting research in university laboratories and peripheral laboratories.

On this point, the five countries reviewed here are much simpler, since the peripheral system is limited and even non-existent in the majority of cases. It follows that virtually all fundamental research is concentrated in the university itself. The result of this should be that with no possibility of escape to other fundamental research laboratories the academic body should develop quite different behaviour and attitudes towards the university, which it should regard as its natural life setting, while the university itself should regard research as a major function.

The role of Research Councils is necessarily adapted to this state of affairs.

1. The physiognomy of Research Councils

The major tendency in the five countries reviewed is to distinguish between fundamental research councils and applied research councils. In this way, we find the following:

Belgium: FNRS and IRSIA,
Norway: NAVF and NTNF, NLVF and NFFR,
Netherlands: ZWO and TNO[2],
Sweden: ten research councils of which five for fundamental research.

Switzerland is the only country which has a single body to finance research and the possibility is envisaged for applied research either of creating a similar fund or extending the competence of the National Fund.

Moreover, as a general principle, research councils dealing with fundamental research do not run their own Institutes. It is perfectly clear why there is only one operational system for fundamental research: a small country cannot allow its research activities to be too widely dispersed in view of its available human and financial resources. What originally came about quite naturally and without any preconceived ideas may well have subsequently become an article of official doctrine and science policy. This has happened, for example, in Belgium, where the biggest institutes in molecular biology (Brussels) and astrophysics (Liège) are attached to a university.

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[1] France, Germany, United Kingdom (cf. Volume 1).

[2] FNRS: National Fund for Scientific Research: IRSIA: Institute for the Encouragement of Research in Industry and Agriculture; NAVF, Norwegian Research Council for Sciences and the Humanities; NTNF: Norwegian Council for Scientific and Industrial Research; NLVF: Agricultural Research Council of Norway; NFFR: Norwegian Fisheries Research Council; ZWO: Netherlands Organisation for the Advancement of Pure Research; TNO: Netherlands Organisation for Applied Scientific Research; STU: Technical Research Council.

Where peripheral institutes exist the desire is expressed, or the tendency is manifest, to re-absorb them in the universities. In Sweden, for example, the Natural Science Research Council has written of its own laboratories:

> "Unlike many foreign Research Councils, the Council, in principle, does not engage in directing its own laboratories. However, things often tend to differ in practice from the theory. Sometimes, groups of scientists appointed by the Council expand to such an extent that it becomes possible to talk in terms of an own laboratory. In those cases, when the Council judges that the Group has really a permanent need for such, it then endeavours to interest the Government to take over the activities."[3]

This is what has happened for the Institute of Optics and, since 1971, the Institute of Palynology of the University of Stockholm.

In Switzerland, Article 3 of the Federal Act on aid to universities of 1968, provides that laboratories recognised to be of public importance thereby become entitled to Federal aid. But since an establishment cannot be recognised unless it carries on a teaching activity, this possibility is not likely to lead to the creation of an autonomous peripheral system. The sole effect of this provision is to allow Federal financing of activities which exceed the possibilities of the Cantons. Examples are the Graduate Institute of International Studies of the University of Geneva and the Swiss Institute for Experimental Cancer Research (ISREC) at Lausanne, whose research was still being financed by the Swiss National Fund in 1972. The Federal authorities seem particularly restrictive in making use of the possibility of "federalising" an institute, just like the National Fund which fully administers one institute only, the Lausanne Institute of Plasma Physics which it created in 1961. Its absorption by the Federal Institute of Technology, Lausanne should be facilitated by the fact that this School is exclusively financed by the Federation. The staff of the Institute of Plasma Physics was 43 in 1971, of whom 12 were research staff, and its budget was S. Fr. 1.9 million.

In Norway the NAVF has in recent years created only a few Institutes which it administers, mainly the Oslo Institute of Dental Research and the Trondheim Radio-Biological Quantification Laboratory. But, like the Swedish Natural Science Research Council, the NAVF has systematically tried to transfer its Institutes to the Universities. The only one still under its direct control is the Radio-Biological Quantification Laboratory, whose 1971 budget was Kr. 300,000 (out of a total budget in 1971 of nearly N. Kr. 39 million) and whose staff numbers six, of whom three are researchers.

The Netherlands represents a notable exception to this pattern. The Netherlands Organisation for the Advancement of Pure Research (Zuiver-

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[3] *Statens Naturvetenskapliga Forskningsrad.* The Activities of the Swedish Natural Science Research Council, 1964, p. 14.

Wetenschappelijk Onderzoek, ZWO), created in 1950 does not itself conduct research, but acts through the medium of Foundations which, at present, number seven:

The Foundation for Fundamental Research on Matter:

(Fundamenteel Onderzoek der Materie - FOM) was the earliest to be created and is the most important since it accounts for half the ZWO budget (about Fl. 30 million). The FOM administers two Institutes, the Institute of Atomic and Molecular Physics and the Institute of Plasma Physics.

The Foundation for Chemical Research (SON):

this is the second most important Foundation for the size of its budget (Fl. 6 million).

The Foundation for Medical Research (FUNGO):

with a budget of Fl. 2.5 million.

The Foundation for Radio-Astronomy (RZM):

with a budget of Fl. 2.7 million.

The Foundation for the Mathematical Centre for Biological Research (BIOM):

the most recent of the Foundations. Its budget, like that of the two preceding Foundations, is of the order of Fl. 3 million. It was increased to Fl. 4 million in 1972.

The Foundation for Bio-Physics:

with a budget of Fl. 1.3 million.

The Foundation for Psychonomics:

with a budget of Fl. 190,000.

The Institutes administered by ZWO are as follows:

Institutes	Financial Aid from ZWO *Thousands of florins*	Staff (numbers)	
		Scientific	Technical (Admin.)
Mathematics Centre (Amsterdam)	2,072	51	53
Foundation for Radio Astronomy (RZM) (Dwingeloo/Westerbork/Leyden)	2,720	15	75
Institute of atomic and nuclear physics FOM (Amsterdam)	3,558	30	71
Institute of Plasma Physics (FOM) (Jutphaas)	3,838	33	99
Institute for Nuclear Physics Research (IKO) (Amsterdam)	7,765	45	131
Isotope Geology Laboratory (IGO) (Amsterdam)	650	6	13

According to ZWO these Institutes were created because the Universities did not have the means for such concentrated efforts in specialised research. These Institutes cannot be compared with the Institutes of the Central Organisation for Applied Scientific Research in the Netherlands TNO, which numbered 14 with a total staff of 1,700 and a budget of Fl. 73 million in 1971.

This is true of Norway, where there are 17 Institutes coming under the Norwegian Council for Scientific and Industrial Research (NTNF) with a budget of N.Kr. 127.8 million in 1970 (of which N.Kr. 93.4 million was spent on R & D activities). The financing of Institutes by the Research Councils in 1970 was as follows (*in millions of N. Kr.*):

NAVF.	3.2
NLVF.	2.8
NTNF.	64.4
Total.	70.4

The advantages derived by the University from the concentration within its walls of nearly all fundamental research and activities are obvious. It benefits from the most advanced research, it does not suffer the drain on its personnel resulting from the existence of host institutions where the best scientists have better facilities and more time for work. Similarly, the public authorities are relieved of the problems raised by turning full time researchers into officials and by the ageing of institutions which are naturally inclined to isolate themselves and become inward-looking. Conversely, the check on the development of advanced research constituted by the traditional university environment cannot be ignored. The obstacles are well known and there is no need to dwell on them: a university structure frozen into a pattern modelled on the research of the nineteenth century, dispersal of resources which the university cannot manage to concentrate, and so forth.

Now, the university system in the countries under review does not greatly differ from that in other countries. On the whole they follow the nineteenth century German pattern which became general throughout Europe. It may therefore well be feared that, in the long run, the scientific drive of these countries may itself be affected. It is somewhat revealing to note that the peripheral institutes have developed precisely in advanced biology and physics, as in larger countries.

There are two sets of reasons for the existence of a peripheral system: one set is human— the desire for total concentration on research in complete freedom from teaching duties, and the other is structural, the desire to liberate research from an antagonistic and stifling environment[4].

The normal process is to constitute a focal point of research and integrate it in an environment in which it can develop normally. It is true that the Research Councils have been able to encourage the creation and ensure the maintenance of focal points of research wherever they may have been situated. But, acting in the university environment alone, the Research Councils have had to modify and enlarge their mode of action.

2. The role of Research Councils: to constitute a focal point of research

Up to now, Research Councils have always visualised their action according to the same principle, and even the same ideology: to encourage science as such, to select individual research projects on a national basis and by the judgement of peers in order to ensure their quality. In this capacity they make material and human resources available to researchers. The Councils finance the whole of the needs arising out of any scientific activity: technical assistants, publications, travel, scientific equipment, etc.

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[4] Cf. *The Research System*, Vol. I, Part II.

The Councils in the countries under review have had to extend this classical range of action to the support of non-teaching researchers working in a university laboratory alongside a team of researcher-teachers. Their existence has made it possible to constitute or strengthen teams which are in themselves too limited in numbers or in time, because university establishments are often calculated in terms of teaching requirements.

All Research Councils award fellowships to advanced students preparing a thesis and associated in this capacity with the work of a laboratory. Except in the Netherlands, the Research Councils in the countries reviewed may pay the salaries of advanced researchers. In Sweden, as in Switzerland, these researchers are sometimes integrated in the university hierarchy with a reduced teaching load. Out of a total of 500 researchers whose salaries it pays, the Swedish Natural Science Research Council has nominated in 1971, 10 Professors, 50 Assistant Professors and 30 Lecturers. In the Natural Science Research Council, as in the Swedish Medical Research Council, contracts are for a term of three years, but may be for an indefinite term when the holders have the rank of Professor. The reason given by Switzerland for the creation of such posts seems to be generally applicable:

> "The aim of this type of grant (individual grants) is to create steady posts on a personal basis for especially qualified scholars. At a time when the universities received no direct aid from the Confederation, establishment of the individual grant enabled Switzerland to retain the services of talented scientists and to facilitate the return of an appreciable number of Swiss citizens who had made their mark in various sophisticated areas of research yet to be introduced in the Swiss universities. The normal university framework lacks departments, posts, laboratories and institutes suited to such new disciplines, and a certain conservative attitude on the part of the faculty boards hampers their acceptance.[5]"

In Sweden fixed term contracts are not automatically renewable and the researchers' field of work is as much of a criterion as the quality of his work when the contract comes to be reviewed and it is not unusual for contracts not to be renewed.

In Belgium, a veritable career in the form of research assignments can be developed in parallel with a university career. Salary scales are assimilated to those of State university staff of a similar category. These assignments are for four or five years in the FNRS (but for one year renewable once in the IRSIA). As in other countries, the FNRS and the IRSIA award fellowships mainly to doctorate students. Post-doctoral research assignments in 1970 amounted to nearly 25 per cent of all fellowships awarded by FNRS, or 180 fellows out of 762.

3. The limits of Research Council action: the environment of research

Research Councils cannot, sustaining university research, change the aspect of the university. Quite the reverse, by slavishly espousing its principles of organisation and structure, they indirectly consolidate the position of the university. By providing it with additional resources, they ensure that, in spite of everything, it can discharge its research function. They therefore do not ask how the research is done, and still less, why. Now, the background of the men, the financial resources and the premises, as well as the structures, cannot fail to influence the value of research which explains the creation of a peripheral system in other countries and cannot be overcome by external institutions through piecemeal activities.

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[5] *Reviews of National Science Policy - Switzerland;* OECD, Paris, 1971, pp. 167-8.

In addition to the structural questions raised in the following chapter, two types of obstacle can be defined which are specific to the university world. One is purely practical, and is rarely talked about, namely the pure question of physical room; the other is psychological, namely the receptiveness of the environment. If research in the smaller countries has not thereby suffered in quantity and quality it is because they hold trump cards: external financial support and a differentiated environment.

a) *The physical obstacle: lack of room*

This obstacle to research is particularly obvious and pressing where there is no peripheral system. Research Councils dealing with fundamental research are usually not in possession of the variable constituted by their own laboratories; they therefore have to intrude into the living-space of the universities, which is outside their control. This feature is all the more marked in countries where deliberate policy is to give priority to the urgent needs of post-secondary education.

It often takes a long time to create research laboratories (five to ten years according to country) and in any event they cannot be created fast enough to cope with scientific expansion. This timelag may result in sterilising skills and may facilitate the emigration of researchers. Too often one finds laboratories well equipped with men and appartus but which are antiquated and bursting out of their seams on all sides...... You start by taking down the doors between the different rooms, then you move into the corridors— already crammed with ultra-centrifuges, photocopiers, refrigerators and so forth; then you descend into the cellars and even the atom bomb shelters and finally you set up temporary huts without even the most elementary safety precautions. Obviously, this state of affairs is most marked in the dynamic laboratories, whose growth rate is commensurate with their scientific value.

In some countries the extension of these laboratories is ensured by private finance. In Sweden, for example, many major biological or medical research laboratories have benefited until recently, from American Foundation aid for equipment, buildings and heavy apparatus (the provision of heavy apparatus from abroad usually being a decisive instrument with which to exert pressure for the attention of one's national authorities and decide them to build up the necessary premises).

To this must be added aid from Swedish Foundations valued at S.Kr 40 to 50 million a year in 1970 (or as much as the budget of the Research Councils for the atomic and natural sciences). The Wallenberg Foundation[6] has specialised in the provision of fully equipped laboratories open to young university teams who want to pursue projects in the natural and medical sciences over a number of years. Research centres of this kind exist in Lünd, Uppsala and Stockholm. The university pays the salary of the young university researchers and the laboratory running costs.

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[6] The Wallenberg Foundation was created by Enskilda Banken. The Foundation has a budget of about S. Kr. 11 million per year.

The aim of the Bank of Sweden Tercentary Fund is to support such research which has a close bearing on the development of society. Its budget is considerably larger than the annual means of the two Research Councils for humane and social sciences.

Switzerland affords a comparable example of aid from the private sector and private Foundations. The "Biozentrum" of the University of Basle (which covers 19,000 m^2) was launched after the chemical industry (i.e. three companies in Basle) had granted S.Fr. 5 million (of the 35-40 million necessary for the realisation of the first stage of its construction). Similarly, a Foundation has been created in Basle to administer the donations made on the occasion of the 500th anniversary of the University, amounting to S.Fr. 11 million. In Geneva, the "Société Académique" manages a capital of S.Fr. 10 million; revenue from this is distributed to university institutes.

Such situations are exceptional, and have only resulted in a slight increase in space for research in Belgian and Norwegian universities. A university which has no possibilities of this kind and which is, at the same time, conscious of the need to organise itself with a view to research, thus has to formulate a veritable land use policy. None has really succeeded in deciding for instance to rent out all its available space to users, thus compelling them to make a more objective assessment of their real needs.

b) *The psychological obstacle: receptiveness*

Up to now, it has been difficult to integrate new fields of research into the context of the European universities, whatever country they may be in. If, in spite of everything, these countries have been able to develop them, and the traditional university has been able to gradually approve them, the ultimate reason is that they had access to sharply differentiated institutional environments.

Perhaps one of the decisive advantages of the small countries reviewed was that all of them, with the exception of Belgium, had two types of universities, the classical universities and the technical universities. The latter seemed more dynamic and more open to innovation than anxious to glory in past prestige. By their objects, their operation and their approach to the questions they have to handle they were in a better position to provide a home for research in new sectors, to adopt what is called an integrated approach and to found new "disciplines", that is to say to legitimate new knowledge.[7] Nevertheless, starting usually from mechanical engineering, they have tackled physics in all its forms and chemistry, but they have not enlarged the range of their activities and research to biology (with the exception, however, of the Federal Institute of Technology, Zürich, which has an Institute of Molecular Biology). When this sector is particularly well represented in the countries reviewed, it owes it to the material aid of the American Foundations.

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[7] Cf. Part IV, Chapter III, "Industry, Science, University". It should also be mentioned that this special feature of the technical universities has also affected the humane sciences. Thus, for instance the psychologist Jung obtained his first Chair at the Federal Institute of Technology, Zürich.

Neither must one neglect the role of initiation which can be played by the Research Councils in initiating new endeavours. It has happened that they have borne the full cost of certain research which they have handed over to the university some years later. This has happened either in fields which were so new that they seemed to have no place in university structures or in particularly new and promising research which merited a risk premium by being exempted from the formal system of grant applications. The Councils have then been able to create laboratories which they have maintained in full, such as the Stockholm optics and palynology laboratories, but most frequently they have mounted full teams which, owing to their size, were not subject to the authority of the university to which they were attached for the purposes of accommodation.

Chapter II

AN UNBALANCED FIELD OF ACTION: THE PREDOMINANCE OF THE TEACHING FUNCTION IN THE UNIVERSITY

The financing of a system cannot be studied in dissociation from its organisation, since the distribution of activities, that is to say, their identification, and even their individualisation, determines the way in which the budget is framed and the pattern of financial flows. But also, and above all, an organisation scheme determines the way in which an activity is recognised and treated. An organisation scheme, that is to say, a structure, is never the only one conceivable, and it is never neutral. The adoption of an organisation scheme means giving preference to one aspect of an activity over another and therefore orienting its results.

Thus, the whole scheme of organisation and financing of universities in the countries under review is based on the primacy of teaching and not of research. The research function is intruded into a structure not designed or adapted to the purpose.

The teaching function is privileged in two ways; the financial needs determine the number of students and university organisation is determined according to disciplines; in both cases it is a matter of "modules", the financing of facilities is determined by the number of students and the internal organisation of universities is defined by the discipline of which, in the end, it is merely the institutional projection.

The systematic use of the number of students to assess needs is a fairly recent tendency. It is explained by the fact that the reception of students in the universities has become the major concern of governments over the last ten years. It is explained by the need felt by Departments to have an objective and quantifiable basis for the calculation of needs so as to programme expansion over a longer period. It makes the allocation of resources more "transparent" by stripping it of usages, or rather of dross, which precluded any reasoned choice.

The question must be asked how the orientation of an activity can be the subject of a policy when its means are determined by the most precise possible finding of a de facto situation. The numerus tends however to be generalised. The countries under examination have adopted it in medicine and engineering; but Sweden and Norway apply it to practically all disciplines except— for the time being— social sciences and humanities.

On the question of the discipline as the basis of university organisation, it must be remembered that science and research are not the same thing. Science is a system of acquired knowledge while research is a process of acquiring knowledge, a system of scientific activity.

Science is subdivided into disciplines characterised by their relatively specific and autonomous character. The criterion of discipline as the mode of organising scientific achievement is the oldest criterion for the structuring of the scientific system. But it is not the only one, and its application to research is neither immediate nor literal. Above all, it appears particularly poor when it is applied to research.

The structure of science resulting from the criterion of discipline is a "tree" structure and not a "trellis-work" structure, to adopt the expression of Henri Lefèbvre, who comments as follows on these two forms of structure:

> "On a tree, the path from one point to another is obligatory (constrained) and unique, it inevitably passes through a specific summit and through a hierachy of summits. It is defined by purely binary relations (bifurcation, dichotomy, etc.). The area is thus fully ordered. Whereas trellis-work and semi-trellis-work allow a number of paths from each point (and even an unlimited number of paths)... The tree is the pattern of bureaucratic organisation; it gives explicit form at the same time to its mental, social, practical and theoretical structure.[1]"

Under the criterion of the disciplinary structure of scientific activities, the scheme of university organisation is equally tree-like, that is to say, hierarchised and pyramidal. Constituted with a view not to research, but to its consolidated acquirements, that is to say, not in dynamic, but in static and fixed form, it starts from the professorial chair or the institute deliberately conceived as the field of action of a discipline and gradually leads to the Faculty, grouping together the research and teaching relevant to allied disciplines. This system, moreover, corresponds to the traditional teaching methods which gave preference to axiomatic approach and deductive structures.

1. The financing system: the quantitative criteria of financing

University financing is not unified. The university has three different kinds of costs: personnel costs, capital costs and running costs. Each kind of cost has its own budget, often coming under different finance bodies and subject to different procedures. The personnel budget, other than for the established teaching body, is often mixed up with the operating budget and heavy equipment with capital expenditure. Financing is far from being co-ordinated and government supervision is much stricter over the capital expenditure budget and the creation of posts than over the operating budget.

The system of assessing needs as it is expressed in the budget of the Department should be distinguished from the system of actually allocating resources which is internal to the university. There is not necessarily any mechanical link between the two, however the needs may be assessed, even by adding up sub-budgets (laboratories, departments, faculties).

The system for deciding how to spend funds covering teaching personnel is more restrictively linked to the assessment than in the case of the operating budget. A university is still usually free to spend the operating budget allocated as it sees fit. This is an essential aspect of university autonomy which, it is true, the universities have so far tended to be reluctant to wield.

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[1] Henri Lefèbvre, *Logique formelle, logique dialectique*, p. 58.

There can be severe restrictions on university autonomy in the matter of teaching staff appointments. In certain Swiss cantons, the universities submit a list of posts to the Department of Education. In providing for these, within the limits of the credits available, the Ministry determines which faculties are to have increases and in particular, which spheres of teaching are to be covered by the new posts. In other countries, new posts are allocated to the universities which then themselves decide what subjects to use them for.

Procedures for the assessing of university requirements have been introduced in these countries, sometimes locally as an experiment (in Sweden for instance), sometimes definitely and nationwide. These procedures are more rigorous, relying as they do upon ratios which, to the extent that they are applied to teaching and equipment requirements overall, operate automatically and globally.

But both in Norway and Switzerland, which have not introduced such ratios, and in those countries which do possess objective criteria, the determining factor is the teaching requirement. It has been observed that in Norway, the Ministers of Education and of Financial Affairs have problems in working out university budgets because the research role has never been assessed and there are no guidelines.[2]

It is in Belgium that rationalisation in the assessment of university requirements has been taken furthest. Different standards have been worked out on a field-of-studies basis for the humanities, pure sciences, medicine, applied science; for each of these a distinction is made between teaching area and faculty area, i.e. the total area required for teaching and research, excluding the area for general institutional administration. For each of these categories a ratio has been worked out in square-metres-per-student; this is multiplied by the number of students forecast for future years to determine how much building will be necessary and what budgets will therefore be required. The standards proposed by the CNPS are higher than the average for Belgian universities and higher than the standards used abroad, but not quite up to the level for many British establishments.

As regards the expenditure of operating credits, a new official financing system based on objective criteria for university expenditure makes it possible to work out an overall budgetary envelope for each institution, within which it is for the individual institution to decide in detail how to lay out the funds available. Whereas the size of a university teaching and research staff is directly related to the number of students, operating expenses as such ought to take account of the size of the university. On the one hand, there is an irreducible minimum of expenditure per faculty and per university; on the other hand, universities beyond a certain size may be able to make substantial economies of scale and to provide more scope for research. "The basic theoretical university" is in the first of these situations while the "standard university" is in the second. The size of the university below which expenses are irreducible is 5,000 students, while the size from which economies of scale become possible is 11,000 students.

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[2] Hans Skoie "The Problems of a Small Scientific Community: The Norwegian Case", *Minerva*, 1970, p. 399.

Public financing procedure for universities tends to become automatic and at first sight the only role for ministry officials, though certainly an essential one, is to compile a set of relevant, accurate and up-to-date statistics. To disapprove of this kind of "decision" system amounts to preferring that a more subjective and also a freer system should be maintained, a system which would have been acceptable as an instrument of policy had it not led to abuse, being open to pressures, to undue weight for established custom and to haggling. The introduction of objective criteria uniformly-applied is an undoubted advance towards openness and the elimination of the arbitrary. Even when decisions taken under the previous system have been acceptable as policy choices, it is fair to ask how well-informed they can have been, and whether the mistakes arising from them may not have been worse than the consequences of an inflexibly automatic centralisation. The best intentioned administrators are the first to ask to be relieved of responsibility for choice in matters where they cannot be aware even of the considerations, let alone the repercussions. Funds may be allocated on a mechanical basis without in any way implying that they must be used mechanically— a crucial point, since it allows for policy to be worked out on a proper basis and consequently to be more realistic, as in the United Kingdom.[3]

The student ratio is now the normal criterion for determining the size of the teaching staff and the volume of equipment. Operating budgets are still worked out in many cases by a uniform increase in the budget for previous years.

The choice of student numbers as a basis for reference seems less open to criticism than the clumsy way in which these ratios are still used, i.e. the fact that they are never weighted, because there is no operating budget for universities (worked out in terms of specific fields-of-study). It is clear that the square-metre-per-student ratio cannot be the same as the international average in a country with no peripheral university system; it is equally clear that a university whose main activity consists of training undergraduates will not require space or even staff on the same scale as a university in which the emphasis is on post-graduate training. The ratios do not however appear to distinguish between undergraduate and postgraduate students.

Finally, with regard to the operating budget, it may appear dangerous to forbid a university freely to lay out the resources which it has obtained with a quantitative system of this kind. Yet this appears to be the trend in those countries in which the ratio system is the most advanced. Apart from the fact that this is to deny a university the means to assert itself and to learn to behave as a policy organ, it is also to ignore the possible arbitrariness inherent in a system of dividing science up into faculties, and the need for research to break out of this rigid framework.

2. The organisation system: the field of study as a basis for university organisation

None of the countries being examined here has any kind of original model or pilot experiment in university organisation to compare with those underway in Germany and the United Kingdom except, perhaps, the University of Tromsö in Norway which will not be operating fully until 1972-1973. In fact one of the striking features of the countries being examined is the widespread traditional system of organisation based on distinct subject-areas through the professorial chair, represented by the institute in research, and grouped together by affinities through the faculty. Whereas the system of the professorial chair is tending to disappear, the importance of the faculty finds confirmation in every reorganisation scheme (except for the new university of Tromsö which only has Institutes).

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[3] Cf. *The Research System*, Vol. I, Part II.

At national level, for example, extreme cases are presented by Sweden and the Netherlands. The inter-university Council in the Netherlands is constituted on a faculty basis[4].

The Office of the Chancellor of the Swedish Universities, which works out university budgets, includes five faculty planning boards, each corresponding to one or two faculties. Needs are assessed on a faculty basis, and this may even be the basis for allocation of funds. Lastly, Research Councils have been set up in such a way that each Council corresponds to a faculty or is subdivided into sections corresponding to the faculties.

The concept of the faculty is rarely defined in the texts of national regulations for the universities of their internal organisation. Such texts usually enumerate the faculties which constitute the university, such as natural science, medicine, humanities, social science, etc., without specifying how the subjects within these are grouped together, which may explain the variation from one country to another in the way certain disciplines are attached to this or that faculty.

The question is decisive, because the faculty constitutes a management unit administratively and for budgetary purposes as it does for the planning of teaching and research. In this way it placed the other units of the university— the sections, departments and institutes— in a subordinate position to itself, with the authority to influence both their orientation and their activity; the faculty is thus an action centre as much as a decision centre.

a) *The faculty as the centre of action*

The faculty may appear to be merely a dependent derivative of the professorial chair and of the institute. Its original function was to coalesce a certain number of these units, already in what might be described as fully-fledged existence, on a basis of their scientific affinities. Since the professorial chair and the institutes had no contact with one another, the only scope for the faculty was in teaching, where it was concerned with curricula and examinations. The faculty was the enrolment and study unit for the students and their home for several years, so much so that it had more meaning for them than for the teaching and research staff.

With the gradual disappearance of the fiefdoms represented by the chairs and institutes and the attempts of the universities to try to organise themselves, the faculty has acquired a genuine importance as an operational system embodying a series of research units whose activities it has to coordinate and whose very means of action it has to determine. The institute or department must consequently pay special if not exclusive allegiance to the faculty on which it depends for its resources.

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[4] Cf. *Reviews of National Science Policy - The Netherlands*, OECD, Paris, 1973.

The inclusion of a field of study or of a laboratory in any particular faculty often comes about by accident or by tradition; although it is rarely the outcome of any reasoned choice the matter is seldom disputed.

But the structures are not as neutral as is often claimed. To make the discipline into a mould is to limit its evolution to the distortions imposed by the passage of time and by sanctified custom. Some approaches may be neglected because the discipline happens to be attached to one scientific grouping rather than another. It has been suggested that Europe's backwardness in biology can be attributed to the fact that microbiology has only ever been investigated in the framework of human clinical medicine and has been limited to the study of the metabolism, whereas the breakthroughs in biology have come about through a close association of microbiology with biochemistry and physical chemistry, i.e. fields of study which, in the classical pattern, would be likelier to come within the natural sciences than medicine. Certain fields of knowledge will be in an awkward situation if they go beyond the framework of their own faculty or if they are too new or original to fit into it in the ordinary way. This applies, for example, to ecology or to experimental psychology which are accepted with difficulty in Faculties of natural sciences and the humanities[5]. Ignorance and negligence towards these "marginal" fields will have undesirable consequences not only at the level of working relationships but also in decisions on the allocation of resources, i.e. in the development of such fields, wherever the rule of the majority and coalitions prevail. A faculty may decline to take charge of a new subject-area which might make too much claim on its resources. It is significant that in the countries under review the expansion of new fields of research comes about through direct support from the central authority of the university, aware of the value of certain sectors and of the state of neglect in which they might stagnate if the university law were to be applied regardless.

The system of internal allegiance on the part of the units towards the faculty is matched by their isolation from the outside, i.e. the other faculties. Relationships between faculties of pure and applied science, or between faculties of science and faculties of medicine, are rare. It is usual for the same subjects to be studied in two neighbouring faculties with no kind of contact; this generally applies to physics, mathematics and chemistry. Lastly, there will be ambiguousness about the attachment of certain disciplines to a single faculty; for example geography is both a social science and a natural science, biochemistry and pharmaceutical chemistry are part of medicine as well as of natural sciences, ecology and geology are applied sciences and natural sciences, experimental psychology is philosophy and biology.

Apart from the new university of Tromsö in the far north of Norway, all the universities have maintained the faculty pattern, though its influence varies from one to another. Special arrangements have been devised to allow for research needs, i.e. the special contacts between organically isolated sectors, but these are comparatively little used in the countries examined; such arrangements include:

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[5] Cf. *Problems and Prospects of Fundamental Research in Multi-Disciplinary Fields: Brain and Behaviour*, OECD, Paris, 1972, pp. 45-46.

- attaching a laboratory to a faculty for administrative purposes, but having it managed by a committee of users. This is the most flexible formula. It satisfied various scientific needs (service laboratories for example) without disturbing the university structure;
- laboratories in a particular branch of science may be grouped together in the same building. The university of Lund has put the chemistry laboratories of the faculties of technology, natural sciences and medicine into the same premises— the first such step to be taken in Sweden. This will be followed by a biomedical centre in Uppsala;
- setting up a university institute. The Free University of Brussels, for example, has set up an interfaculty geological institute to promote teaching and research in all fields of study relating to earth sciences. In the same way partially at the instigation of industry, the Canton of Basle has set up a Biozentrum to group together biological research throughout the university (biochemistry, biophysics, microbiology, pharmacology, cellular biology). To avoid disturbing the organic structure of the university, the Biozentrum has been given the form of a faculty while remaining an autonomous public establishment;
- setting up inter-faculty research groups. This approach obviates the need for an institute as such, yet despite such clear advantages as limited cost, flexibility in development, and the ease with which it can be introduced it is seldom used. It is a painless way of introducing new fields of research into time-honoured scientific centres. At the University of Ghent, the grouping together of research workers interested in the nervous system into one coherent project has led to results of international value. The university has used this as a model in setting up an inter-faculty centre on pollution.

b) *The faculty as a decision centre*

The faculty constitutes a unit of management. There are two points at which faculty bodies intervene— in preparing the budget and in allocating funds when the budget it put into application. At the first stage, the faculties are responsible for grouping the budget assessments of their units together and for a preliminary breakdown of the credits, taking account of the financial prospects for the forthcoming year. The faculties are all the more influential since practically none of the universities in the countries being studied has any central research committee or scientific secretariat responsible for financing or orienting university research. On the other hand, it is not unusual for departmental or section committees to be set up and given powers on research matters.

An as example, the case can be quoted of certain Swiss universities in which reforms are currently under way. The project of the new University Act of the Canton of Geneva provides for the introduction of a management body at each level of organisation, and except in departments which are subdivisions of the section, of a deliberative Council. The Act provides that the management and deliberative bodies of the sub-divisions shall normally have authority within the limits of their fields of activity along the lines of the central university bodies. As regards the elaboration of the financing plans and development programmes, the sections of the faculties deliberate on the plans within their sphere for the university council which is the competent body at the university level. The latter will approve financing plans and development programmes at medium and long term.

In parallel with the recognition of subsidiary units the universities are sometimes tending to create or to consolidate central powers, those vested in the rector and/or in councils which can be made up of individuals outside the university. The result can be to weaken the power of the faculty, hemming it in to some extent between two powerful bodies. But these bodies are often a projection upwards or downwards of the power of the faculty. Furthermore, the powers granted to the faculties are still frequently designed as a counter-weight to the central power of the university whose growth is regarded with suspicion.

c) *The faculty as an instrument of communication*

It may come as a surprise that the reforms currently under way should be consolidating the Faculties rather than reducing their influence by giving priority to the departments or sections. When asked what their reasons were for supporting and for being satisfied with a pattern of faculty organisation designed as a coherent grouping-together of disciplines, faculty staff put forward two main reasons:

- at the operational level, the faculties constitute a coherent whole, people are talking the same language and problems are approached in the same way. The faculty has its own way of doing things. This makes for easier contacts and more frequent changes of view, occurring more naturally and spontaneously;
- at the decision level, the faculty is a valuable counter-weight to the central authority of the university.

Experience of the past does not altogether confirm these arguments. The faculty may be the crucible for a common language but this carries the risk of ignoring other equally enriching languages. It is incidentally a matter for surprise that the faculty experience should not have facilitated this kind of communication and not made it easier for "disciplines" which would have had everything to gain from a dialogue to put themselves forward. It is as though the faculty had not facilitated contacts within itself or at any rate, as though contacts among disciplines within a given faculty were no longer adequate to ensure scientific progress. A comment which applies to teaching as much as to research.

To those who would argue that the genuine contacts must in the last analysis be individual and informal and that the structures make no difference, it could be replied that in that case there would be no need to retain such heavy and formal structures. Besides, where research is concerned it is not certain that informal contacts, desirable as they may be, will in future be adequate. Such contacts may have been satisfactory when research did not require too much in the way of apparatus, when the teams were restricted in size, when scientific progress was essentially linear and also when the finance or research was comparatively uncomplicated. At a time when the very work involved is becoming increasingly collective, specifically individual and bilateral types of relationship are no longer adequate. These collective relationships can moreover be established along flexible and uncumbersome lines and be less ponderous than enriching: the post-graduate seminars, regular reassignment of premises, research committees, the sharing of time and of costs on a particular piece of apparatus, the movement of research workers from one group to another etc. They need to be formalised to encourage the movement of information, which is still inadequate in the universities, and to facilitate intelligent utilisation of resources in terms of time, of space and of funds.

Looking now at the faculty as a decision-making system, past experience has shown that the faculty has not allowed for the taking of real decisions, that its effect has too often been to over-ride initiatives and consequently to consolidate the existing state of affairs. There are two grounds for criticism: excessive size leading to mutual ignorance and thus to a decision-making system in which haggling prevails. An assembly of 50 or 60 individuals, each master of a fiefdom and more or less unconcerned with anyone else, is in no position to take courageous decisions when sharing out limited resources. As has been well said by the Constituent Committee for the University of Tromsö in Norway:

> "The existing faculties are often too big and heterogeneous for a sensible academic discussion. If the unit is getting so big that concrete academic understanding and insight between the members is generally absent, it seems to be more sensible to raise the planning and necessary priority decisions upon a central, joint level where all considerations, internal as well as external, can be evaluated as a whole."

In connection with operational rather than policy-making functions, the report adds:

> "The technical and social centres of gravity at the university are formed by the smaller units. It is also here that most questions of importance to the internal activities of the Institution should be decided. Equalitarian and democratic conditions at the university are best promoted by delegations of more decision-making powers to the smaller units at the ground level of the Institutes, where the academic as well as the social areas of contact are greatest and where also the close contact with problems gives better opportunities for everybody, in their different ways, to participate in the decision-making processes."[6]

That a single university should have been able in isolation to grant itself the privilege of challenging the principle of academic disciplines as the basis for organisation, is due to the fact that the disciplinary structure of the scientific system very closely matches the sociological, psychological and even ideological structure of the scientific community. The disciplinary criterion is not therefore merely an intellectual tool, but a social relationship as well. This is what makes it difficult to challenge and perhaps makes the formulation of university policy still more difficult.

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[6] Universitetet i Tromsö, Innstilling fra Målsettingskomiteen, March 1971. In 1971, Committees at the Universities of Bergen and Oslo also presented reports for a more democratic university organisation.

Chapter III

AN UNFORMULATED UNIVERSITY POLICY

The university system, and the research system generally have up to now been shaped by an infinity of detailed and isolated decisions. Everything has been done on the principle of classical liberalism, based on the individual and on "laisser-faire". The individual has been the generator of action and the end object in a system whose function has been to serve intelligence in itself. These individual, isolated decisions were believed to adjust themselves naturally at the level of the university as a whole, and to maintain satisfactory advance in the frontiers of knowledge, just as a mosaic, even though it is made up of separate components, offers a satisfactory picture when viewed as a whole.

These principles can in fact lead science to something near inertia resulting in incoherence in the organisational and decision-making system, within which academic freedom might find its best protection. The system of recruitment by co-option, the personalising of scientific disciplines at the highest point through the professorial chair, the right to equal finance for everyone's activities, ensured that research would proceed slowly along the recognised channels and in the recognised sectors of science. The introduction of the Research Councils has made it possible to crack the scientific intertia of the university system; they have enabled strong individuals to assert themselves. But they have based their action on a purely scientific assessment of individual projects, adjudicated upon by more or less eminent peers.

For the future, decision and action ought to be founded on an entirely different basis: on the one hand, the institution must take precedence over the individual, who can no longer isolate his scientific activity or even his research from its context; on the other hand, the coherence of the research system can only be guaranteed with a properly thought-out approach involving selection and therefore rejection— in other words with a policy and a policy for action, not conservation, and an explicit, not implicit policy. Nowadays, everything needs to be assessed in the light of a composite entity whose coherence, it may be repeated, should be given priority.

The implications of this are beginning to be understood. The interdependence and interlocking of all the components of the system to a need for full consultation and co-ordination between Councils of the universities, the universities themselves, the universities and the national science-policy authorities. For the system to continue to function in all its complexity, what is needed is perhaps not so much that it should be organised as that its functions should be defined. At the decision level, choices should be based on a concept of relevance and no longer merely on an assessment of quality in itself. Such choices can only be made upon a basis of the most accurate and broad information possible.[1]

The research system has become so complex that it must be decentralised. If this gives the university a certain autonomy, its autonomy should be thought of as a concerted participation by the institution in a combined effort, and no longer as a wall to protect the individual, his chair and his laboratory in the name of an academic freedom which has become purely formal. At this point the concept of maximisation of resources which is valid for the financing of isolated units ("the more resources a laboratory has the better") should give way to the concept of optimisation, defined at the level of research overall.

Which direction should be pursued in research has hitherto been decided by individual choices of members of the national scientific community itself, in the light of international trends in research; this will no longer be possible. For one thing, science evolves along too broad a front; choices have to be made in the light of the internal development of such countries. Again, funds available for research are too scarce for sorting projects into the worthy and the unworthy to be adequate to ensure that those resources are well used. Projects and teams of equal quality must be traded off against one another and it therefore becomes desirable to obtain further criteria, which will not be scientific.

The relationship between the research worker and his environment would be a matter of continuing concern. Direct links between the Research Councils and the research worker should be enhanced with consideration of the research environment and of its requirements, i.e. the university as a scientific collectivity. This means that every university should think of itself as a policy organ[2] and that the research workers, like the Research Councils, should concert their intervention and action with such a framework.

1. The elements of a coherent research policy

A policy is a set of decisions for achieving specified purposes.

— Decisions should be based on the fullest and most accurate possible information; this is not yet the case in the university system.
— Decisions are expressed in terms of a budget which implies that the budget should be worked out in such a way as to become the instrument of a policy.

a) *Information*

There is more to information than merely an organisation chart with activities labelled and ranked as a guide to students or to the public auditor. The university is much more than a skeleton. Information does not necessarily mean verification, it is not necessarily an instrument of constrain, and as it is not materially identified with an organisation chart, it can cut across structures to take account of particular aspects of their activities. The role of information is to help with the taking of well-founded decisions;

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[1] For example, it is undesirable that an institution should be prepared to finance laboratories without knowing anything about their other sources of income.

[2] Cf. *The Research System*, Vol. I, Part II.

in a more subtle way it may have the additional role of making the individual realise that he belongs to a community from which he cannot detach himself and in relation to which he should consider his action. It is for this reason that the introduction of a university information system comes up against so many difficulties and encounters active and passive opposition based on the so-called principle of academic freedom.

i) *Information on resources*

The external resources available to university laboratories are substantial in the countries being studied here. This is mainly because the Research Councils possess practically no laboratories of their own and allocate a major proportion of their resources to the universities. Secondly, except in Belgium and Norway, industry and the foundations play an important role in financing university research. It is not unusual in these countries for physics laboratories to receive more than half their budget from outside; 40 per cent of the research costs of the Chalmers university (Sweden) are financed externally.

Traditionally, academics are under no obligation to declare such additional resources — held to be exclusively and personally theirs— to the university. In the Netherlands and most Swiss Cantons, which have regulations stipulating prior approval on the part of the university or certain of its bodies for such finance, these regulations are very rarely applied.[3]

In these circumstances, a university budget is meaningful only in terms of obtaining funds, not in managing them. This becomes all the more serious since external resources are used to acquire what may be substantial items of equipment which may be costly to operate (sources of energy for example) and may require an exceptional amount of space. Most of all, however, since these external resources are not declared, it is impossible for the university to take account of them in weighting the funds made available to it.[4] Supervision may take many forms: there may be preliminary or spot checks, used in some universities to control contracts with industry. Supervision may also consist of no more than ascertaining the relevant details with accounts for the sums involved being kept by the university. Or, supervision may go as far as the administration of the account by the university. This involves the university in operating an analytical system of accounting with each unit having a budget of its own listing all the resources available to it— from the university and from external sources— against which expenditures are to be charged. This is the situation at the university of Louvain where the accountancy system has been modelled on banking practice. This management system, being purely mechanical, does not interpolate any kind of control over the choice of purchases of the type of expenditure. It greatly simplifies the administration work of the units and of the research staff.

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[3] The Secretary-General of a major university in the Netherlands has arrived at a figure of 5 million florins for such additionnal resources and the actual sum must be in excess of 7 million.

[4] This problem does not affect the recruitment of staff; the existence of a social security system makes it compulsory for such staff to be declared and for the university to administer them.

ii) *The gathering of information on activities*

Information may also deal with activities. Here again, there are several ways of envisaging this.

On the scientific level, this would involve collecting information about research programmes for the various laboratories in order to publish it. Publication is vital to encourage communication. Research programmes should be covered in the same way as course programmes. Unfortunately, this has not yet come about in the universities. The national Research Councils in Belgium, the Netherlands, Sweden and Switzerland regularly publish details of such projects— the individuals and laboratories concerned, the objectives and duration of the project, the sums of money involved.

Considered at the budgetary level, information on activities is much more general and takes its place as part of the attempt to work out an operating budget for the university. The budget is then a planning instrument in that the items of expenditure are linked to the objectives of programmes of activity. It is a question of distinguishing the major activities of the university and isolating research among these so as to determine its scope. Expenses are generally expressed in terms of resources, against which they are charged. University management does not allow for costs to be evaluated by activity or by programme, the cost of training in the exact sciences compared to the cost for such training in the biological sciences, for example, or the costs of the research function in the various sectors compared with other functions, such as teaching in the same sectors.

The problem is, first, to distinguish all the elements or variables having an effect upon research activity. However, some of these elements come under more than one activity or programme (teaching, research, services, biological sciences, exact sciences etc.) and it is impossible to distinguish directly in what proportion they come under each of those. The experts admit that practically all costs are shared. Investigation has naturally started with staff time allocation and it has been this aspect of the value of rationalisation techniques that universities have been debating. Assessments of this kind have been carried out on a national basis in the Netherlands.

The work under way in Belgium, the Netherlands and Sweden has not yet reached the stage where it can be used as the basis for models of university research. Nevertheless there have been attempts to devise such models, providing an interesting glimpse of the physiognomy of certain universities.[5]

b) *An operating budget*

In the countries under consideration here, the universities have endeavoured to introduce the elements of a university policy through their procedures for assessing medium-term requirements and through detailed allocation of resources.

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[5] Evaluation Conference on Institutional Management in Higher Education, November, 1971, CERI-OECD.

i) *The determination of a framework for medium-term development*

The development plan concept has reached the universities not without appearing to many of them as a revolutionary innovation. Thus the rectorate of the University of Geneva, in the introduction to its first four-year Plan for 1971-1975 writes:

> "The very idea of establishing a four-year development plan for the university was revolutionary. It must not be forgotten that the Development Committee had no earlier experience to rely on since up till now no other Swiss university and not even any Cantonal administration had ever taken such a forward study."[6]

It will be noted incidentally that in the countries examined, certain universities have managed to come into existence without being the subject of any plan to determine their functions, their orientation or the speed at which they should develop. In this connection the University of Tromsö is again a noteworthy example, since a Committee had spent a year on a careful study of the shape to be taken by this university.

Development plans are tending to become more widespread in the countries studied. Such plans are often required by the national administrations and have the advantage, from the point of view of the university itself, of making the academic community aware of its close dependence upon its economic and social context; the university is obliged to think itself out and to define itself collectively, to act as a concerted whole, to consider expansion only on the basis of mutual interdependence, thus giving precedence to the collective notions over individual situations and reactions. But the difficulties of this kind of programming are not to be minimised; it is because of these difficulties that research has so far been no more than lightly affected by programming.

The problems in devising and utilising such programmes stem from a number of factors which are particularly well-covered in the Geneva University document quoted above: they are connected with the "slipping" character of the Plan, i.e. the fact that it is drawn up each year for four or five years to come, and with its coercive restrictive and prospective character. On the last point, most of the universities must at present confine themselves to gathering quantative data— assessment of student numbers, higher credits and the posts and premises implied by the increase and basing projections on these is the accountancy side of the problem. As the rectorate of the University of Geneva puts it: "More money and more staff will not be enough, by themselves, to create or develop centres of excellence within the university". The teaching and research objectives of the University need redefining, and it must be specified how much weight is to be attached to the various aims and activities.

This exercise calls for skilful handling of a considerable number of factors and variables such as:

- the needs of the community;
- the present-day requirements of science;
  (development of certain disciplines as a basis for the evolution of other disciplines);

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[6] Proposals for a four-year plan 1971-1975 for the University of Geneva, Geneva, May, 1971.

— the capabilities of the existing teams and recruitment possibilities;
— the development of other universities within a wider setting.

ii) *The distribution of resources*

The role which the university can play in this area depends in the first place on how restrictively resources are allocated. Are they made available on a faculty basis, or to the university overall? Are new teaching posts granted according to the type of teaching— i.e. according to the faculty— or to the university, or according to discipline? It is in the distribution of the operating budget that the university has greatest freedom, and it is here that the university ought to be able to carry out a policy. It is necessary that the procedure for distributing the budget should not be pre-empted to any extent by the procedure for working it out.

Here again, vested interests often play a particularly restricting role. The yearly distribution by successive instalments usually presupposes a large number of individual applications, inspired by policy decisions or hypotheses which are difficult to discern. This climate leads to a compromise outcome stemming from the play of politics.[7] Such play is all the more natural, to the extent that the structure of a university is practically never challenged. In direct contrast with the University of Sussex, which resolved to reform its internal structure every year,[8] there are practically no examples of the disappearance or merger of units of activities over a long period.

In contrast with what is called "zero" or overall budget stands the marginal or incremental budget system. Under this system planning takes account only of new resources which, after deductions for recurrent charges, are extremely limited. Does planning retain any meaning here? In most cases, certainly not. There are however two examples which demonstrate that marginal attribution of credits, can, when properly thought out, be the element of a policy. One of these is Louvain (French language) and the other is Basle. The system at Basle used to be sharing-out of an increase in the limited resources, which did not allow for the normal development of existing activities; at Louvain on the other hand there has been an innovation in the setting up of a central fund as a substitute for a global policy resulting from a pluri-annual development plan. These two examples are also interesting because they are based on opposite approaches.

Since 1970, the Canton of Basle has restricted the increase in real operating funds for the University to 2 per cent (the nominal growth of the budget being from 8 to 9 per cent) giving the University, in return, the freedom to allocate this percentage as it sees fit. At the same time, the Canton credited the University with the money-value for vacant posts so that the university can transfer such posts if it so wishes. When calm had returned it was decided that the Government, in consultation with the University, would appoint a Committee to put forward proposals for distributing the funds to the University. The Committee consisted of 14 members, each faculty being represented by at least one member excluding any directors of institutes. The Committee, made up of unopposed individuals, has produced no reports, made no theoretical analysis of the situation and set forth no criteria to guide its decisions. It has worked pragmatically, quietly, visiting the laboratories and asking questions, and has been in frequent discussion with the scientific community in the University. The Committee has taken meticulous decisions which have not been challenged by the faculties. The new university will give formal status to this Committee.

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[7] A. D. Albright, *University Management in Belgium*, Institut Administration-Université, Brussels, 1970.

[8] Cf. *The Research System*, Vol. I, Part II, Annex 2.

The Scientific Development Fund of the University of Louvain was introduced in 1969 when it had proved impossible to use the first five-year Plan to reorient the activities of the University. A remedy was found by setting up a scientific Fund at the disposal of the rector, or more accurately of the scientific Secretariat at the University. This Fund was to stimulate development of scientific and innovatory achievements at a more rapid pace than was allowed for by the average growth of the University budget. It has been set up for 15 years, with about 50 per cent of the increase in the yearly resources of the University.

The University managed to have the Scientific Development Fund (SDF) relieved of the obligation to share out its resources to each faculty on the basis of the faculty's quota in the general budget.

The budget for the SDF and the projects it has taken on are as follows:

The Intervention of the Scientific Development Fund of the University of Louvain, French Language

FB Thousands.

Year	Budget	*of which:*		
		Cyclotron	Other projects	
			Number	Amount
1969	59,800	22,500	28	37,300
1970	39,700	10,000	23	29,700
1971	55,400	30,000	28	25,400

This Fund provides finance not for units but for specified projects, which may not take more than five years to implement. These projects can be of two kinds:

- "big projects" in collaboration with the Government and other sources of finance, with a view to the setting up of a new department. The university cyclotron and an institute of cellular pathology have been built in this way;
- "breakthrough attemps" in connection with the science policy of a faculty, a number of faculties, or of the whole university. This consists of providing one man or team of distinction, working in a field which has strong hopes of scientific innovation, with the opportunity to develop an innovatory project. Finance has been provided in this way for a programme on organ transplantation involving experimental surgery, haematology and immunology.

When such projects have reached the end of their original life span they are transferred to the faculty envelope. Those not taken over by a faculty or by external funds are closed down.

The procedure is as follows:

- in February, faculty deans and scientific counsellors put up a list of various projects, with reference to a scientific development plan, to the Academic Council;
- in March the Academic Council makes a preliminary comparison and selection and sends an application file to the selected promoters;
- these files are examined in April and May by the Scientific Secretariat and the final decision is taken by the Academic Council at the end of June.

The projects are examined against a combination of the following criteria:

- past scientific output of the promoting team (examined through the Science Citation Index and the Ulrichs);
- the potential worth of the team set up around the project;
- the prospects for a breakthrough in the field chosen;
- how the project is co-ordinated with the science policy of the university faculties and/or of other universities;
- the interdisciplinary character of the projects;
- the prospect for "fall out" on other research units;
- social objectives.

Projects are accepted in the order of assessment up to the limit of the financial availabilities of the Fund.

Current projects are examined every year to be closed down, held back, maintained or developed in the light of the results and of any external support obtained.

2. The elements of an integrated research policy

a) *Inter-university concertation*

The need for universities to come together on research has only recently become apparent. Before this could happen the universities had to become aware of the need for a university research policy; they also had to be prepared to talk to one another and to enter into commitments as universities.

Contacts between universities had previously taken place at conferences of rectors, i.e. individuals who, even when representing a university, were not in a position to commit it and did not generally discuss any matters relating either to research or to the distribution of resources.

Three of the five countries examined— the Netherlands, Sweden and Switzerland— have set up agencies which could discharge these new functions in concert.

Sweden has a centralised agency, the Office of the *Chancellor of the Universities*, essentially an administrative agency responsible for, among other things, preparing budgets for higher education and research (the universities).[9] From 1964 the Chancellor of the Universities has no longer been the elected representative of the Universities. He is a senior civil servant belonging to the central administration presiding over the Executive

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[9] The Office consists of five divisions: planning, education, educational research, administration, rationalisation.

Committee which is made up of ten individuals appointed by the Crown. Five represent the various professional, trade union and student organisations and five are the Chairmen of the Faculty Planning Committees. These five planning committees represent the corresponding faculties in the universities of Sweden: liberal arts and theology, law and social sciences, medicine, dentistry and pharmacy, mathematics and natural sciences, and technology.

Their function is to plan research and education in qualitative and quantitative terms, for the allocation of resources and the attribution of posts. The committees are made up of a chairman and eight to ten individuals of which five represent faculties (which will have elected them). The Office sometimes likes to compare its work with the University Grants Committee in the United Kingdom.

In *Switzerland* the role of concertation, among universities on the one hand and among the Confederation and the Cantons on the other, has fallen to the *University Conference*. In fact, given the backwardness of the universities in collaborating and the mainly financial terms of reference of the institution, the Conference is more a political organ for co-ordination between the Cantons and the universities than between the universities themselves. Its duty is to examine the requests for grants submitted by the Cantons to the Confederation under the Universities Assistance Act (covering basic grants and ad hoc grants for investments). The Conference examines applications from the standpoints of inter-cantonal co-ordination and national higher education policy before forwarding them to the Science Council. In 1970-1971 the basic grants amounted to some 15 per cent of the actual operating costs of the universities.

The *Netherlands* has introduced the most novel agency in its *Academic Council*, a purely university body which deals directly with scientific questions. Created under the University Education Act of 1960, the Academic Council was reformed in 1970. Each of the 13 universities is now represented on the Council by three members, one being the University Rector, the two others being individuals elected by the university councils (not in a personal capacity but as representatives of the institution itself). In addition to the university members there are six members appointed by the Crown for ten years, to represent the interests of society. They are not entitled to vote.

The Council has set up nine committees for general scientific problems and 39 specialist scientific groups. Lastly, it has set up ad hoc groups for specific questions (earth scientists, environmental sciences). The faculties concerned are always represented in these groups.

The Academic Council is assumed to speak on behalf of all the universities. It is not designed as an administrative body or as a meeting point between the administrations and the university. It is much more a spokesman to the government for the universities, advising it on their behalf. It does not deal with the problems affecting them all. Its recent reorganisation should make it much more effective as a co-ordinating agency than in the past.

Except for periodical meetings of the university rectors, *Norway* has no co-ordinating and planning body for the university development. It seems to be generally agreed, however, that final decisions should be taken for the political authorities, i.e. by the Ministry of Education, which, within the limited resources available has a considerable influence by means of the budget string. The political consensus, that the new university in Tromsö should receive favourable treatment, creates some difficulties particularly as a result of the pressure on the established universities caused by the "student explosion".

b) *Inter-university co-operation*

Coherent patterns for specialisation can be worked out with an agency such as the Academic Council of the Netherlands as their starting point. When central bodies are not in a position to carry out such a task, direct negotiations between the universities may do so. This applies for example to the universities of Switzerland where French is spoken, which feel enough affinity to organise themselves on a regional basis and to share out the subjects, in broad disciplines or even by faculty, among themselves. The universities are moving, in a less concentrated way, towards the introduction of university institutes of French-speaking interest financed by the three universities where French is spoken. But this is only a first step as the Belgian inter-ministerial committee on water pollution says in its report: "collaboration among universities should not restrict itself to jointly sharing out the tasks, but should eventually lead to their combining to organise certain post-graduate subjects, in which the best specialists of each of our universities could participate as members of a team".

The inter-universities institutions in the Netherlands may achieve this. Most of them were set up in 1970, there were 12 in existence in 1971 with never less than three universities in each.[10] Some of these institutions indeed comprise scientists from all the universities in the Netherlands. This approach is being used in the pure and exact sciences for the nuclear reactor of the University of Delft (with an operating budget of 8 million Florins and a staff of 162), for the Amsterdam Institute of Opthalmology of Amsterdam (3 member institutions, 17 staff, and a budget of 700,000 Florins). Funds for these institutions are in principle provided by contributions from each of the member institutions.

In Norway, a Council for Physics was established in Autumn 1972. In order to continue improved collaboration between fundamental and applied research, the Council is composed not only of representatives of the universities but also of representatives from applied research institutions, i.e. the Central Institute for Industrial Research, Oslo and SINTEF, Trondheim. A Norwegian Oceanographic Committee was established in 1971, with a view to providing a forum for co-ordination of activities in this field. The Central Committee for Norwegian Research has encouraged the establishment of these two bodies, which, if needed, may be followed by the creation of similar bodies in other subject areas.

c) *Scientific co-ordination*

The Research Councils when they allocate comparatively substantial resources to the university, can to some extent decide what its poles of development are to be. The choice of location for a laboratory or item of equipment may be governed by a policy. But in that case if the decision is to make sense it should take account of all the variables which constitute an environment. The Research Councils have too often acted on the basis of scientific criteria whose value and influence have often been determined by the various pressure groups within the scientific community.

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[10] The list and membership are given in *Reviews of National Science Policy - The Netherlands*, OECD, Paris, 1973.

These weaknesses are too well known to need describing. It will be more useful to indicate ways in which the Research Councils have been able to bring about a better awareness of the medium in which they must begin to act and better communication with other policy and research agencies.

The elements for institutional policy co-ordination can certainly be discarded. In Belgium and the Netherlands the statutes of the Research Councils provide for university rectors to attend the Board of Governors or of Management. In Norway, a majority of the members of the NAVF are nominated by the universities.[11] In Sweden and in Switzerland, the councils include elected representatives of the universities. But whatever the institutions or machinery set up, their effectiveness is partly bound up with the spirit in which such contacts take place.

In Switzerland relations between the university conference and the Swiss Science Council are particularly close and no important decision takes place without both institutions discussing it beforehand. The Conference forwards requests for grants from the Cantons to the Science Council with its comments and in the other direction "it establishes, in the light of the directives of the Science Council, the rules for distributing work among the institutions of higher learning and the measures to be taken jointly". In the same way it gives its opinion on the general problems put to it by the Science Council. The Conference studies the problems inherent in setting up new universities and puts forwards its proposals to the Science Council. The contact between the University Conference and the National Fund is assured by the fact that one member of the Research Council represents *ex officio* the National Fund at the University Conference, and also by the presence, with a consultative vote, of the secretary general of one institution at meetings of the other. For problems of mutual interest, the two institutions consult each other.

The Swiss National Scientific Research Fund has taken two original initiatives. It has created in each university a research commission whose members are freely designated by the university, and which acts as a liaison between it and the Research Council. These commissions receive an allocation of resources from the National Fund for scholarships to young research workers. In addition, they give the Research Council information on the requests from professors and institutes of their universities. They indicate more particularly if installations and personnel available will allow research to be undertaken in satisfactory conditions and if the research will enter harmoniously into the perspective of the development plan of the university (where such plans exist).

At the beginning of 1971, the National Fund created a scientific equipment service which now is able to assist members of the Research Council, applicants and beneficiaries, on all questions concerned with instrumentation, choice, rational use, upkeep and employment. The National Fund only allots credits for the purchase of research instruments. Contacts established with the University Conference and the Division for Science and Research have strengthened reciprocal information for an improved coordination of the distribution of tasks.

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[11] In Switzerland, 28 of the 34 members of the National Council for Research are elected by a council formed, in the majority, of representatives of universities, polytechnic schools and learned societies, six members being designated by the Federal Council as representatives of the Confederation. Each of the scholars taking part in the Council represent his own discipline; none represents his university or school.

In the Netherlands where there are no formal links between the ZWO and the University authorities, the ZWO send one copy of every application for a grant to the university concerned so that the university can comment on it and take account of it in its activity.

In Sweden the Natural Sciences Research Council discusses all creations or renewals of university posts having any scientific bearing with the Office of the Chancellor of the University.

The influence of such initiatives is difficult to assess. Presenting its distribution plan for 1971, the National Swiss Research Fund found it necessary to comment by way of a final consideration: "The National Fund is and will necessarily remain to a large extent a tributary of the requests it receives. The universities and the polytechnics pursue their development without consulting it. The Fund cannot therefore plan ahead as much as it would like and since users neglect to inform it, the Fund finds it difficult to make forecasts".

CONCLUSION

The striking point for an analysis of the organisation and financing of fundamental research in the smaller countries under review is the lack of laboratories peripheral to the universities. The advantages which these countries derive from this are considerable as they do not experience the problems of research careerism and of communication which are common to other countries. But the absence of a peripheral system can make a satisfactory link between the missions of teaching and of research, traditionally assumed by the universities, all the more essential. Whereas the occupational purposes of the technical universities have ensured that both functions are constantly adapting to the requirements of individuals and of society, the same is not true of the conventional universities. It seems clear that the university system in these countries is not managing to meet the requirements felt in teaching and research, either at the level of the resources needed or at the level of achievements, financially or operationally. Still less are they managing to validate the link between teaching and research or to provide for cross-fertilisation between them.

The universities claim that their problems would be solved by increasing their resources and working equipment enabling them to improve the quality of the teaching and to carry out a vital minimum of research. In fact, it does not seem possible to provide a quantitative solution to a problem which is concerned with orientation, with the concept of the university and can only be approached in the context of the whole education system.

For while the universities may hold something of a monopoly in scientific non-oriented research, they do not monopolise teaching. The disenchantment of students with conventional teaching of which the universities have made themselves guardians in the name of the requirements of pure research, is matched by the will of most governments to diversify education to fit it more closely to the needs of society and for a fully personal training. Beside the technical universities short-term educational institutions are proliferating and will continue to do so in the five countries discussed here. They are growing at a faster rate than the science faculties. This suggests the conventional university in these countries will be able to reconsider the link between research and what will no longer be mass education and that they will be able to redefine this link other than by reference to a received idea.

If some universities in these countries were to take such an option, they should think on the one hand in terms of research oriented more towards usefulness for society and not towards science considered as the advancement of systematised and codified knowledge, and on the other hand they should define teaching with reference to the new functions of research. The characteristics and needs of research oriented towards social problems are too well-known to be developed here.[1] But it would be particularly interesting to investigate what form these characteristics and requirements take for a university, in terms of its internal structures and of its relationship with society.

None of the countries being considered has yet formulated an analysis of this kind on the basis of new prospects for research. The structural reforms currently under way in the universities are reinforcing a pattern of scientific organisation which may satisfy a scientific community, but is liable to neglect the needs of research over the next ten years. The efforts being made to rationalise university management with new management techniques are concerned with information. It is not even their purpose, let alone their effect, to reconsider the decision-making system of the internal structures. Data processing could well become an instrument for conservation and consolidation. In the same way the universities do not seem to have defined or even to be in a position to define an integrated policy for their activities— one parameter of which ought to be the geographical environment. Finally, their development plans are never more than medium-term assessments of growth in numbers and the corresponding financial requirements.

There has been some worthwhile thinking about the part played by additional research finance from the Research Councils. Suggestions have been made here and there that the Research Councils should no longer be content with distributing limited resources as an adjunct to the university budgets, but take over the whole of whatever proportion of university budgets is in principle destined for research. Suggestions of this kind appear to be intended to safeguard a certain type of research activity in a medium which is becoming more and more asphyxiated by the needs of teaching. Such suggestions lose much of their value however if they failed to give consideration to the suitability of university structures for research and the method of approach of the Research Councils. They could certainly facilitate better communications between Research Council policy and the activity of the universities. On the other hand it seems that the Research Councils have too often failed, when intervening, to challenge or even to modify university structures. The methods for selecting and financing projects have been established on the basis of a research worker who also teaches. The question arises of how far the piece-meal, dissipated financing of individual projects isolated from their context is still meaningful, or whether the end result may not be to bolster up anachronisms rather than to encourage the development of research. It is significant that over the last 20 years in the countries being considered, the average size of a laboratory, usually centred upon some individual, has hardly changed, and that whatever the breadth or density of contacts within the scientific community, collective research is still unusual. The ZWO communities and the planning groups of Sweden's medical research Council are exceptional examples and would repay close attention.

There is no doubt that the Research Councils have a major role to play in the development of the universities and the reorientation of research. Although their budget hardly amounts on average to more than 10 per cent of the university budgets, they are in a strategic position. To start with, they can set research priorities not only in terms of disciplines but also in terms of multidisciplinary or even transdisciplinary approaches. Whereas the Swiss National Scientific Research Fund is obliged to allocate its subsidies according to the distribution plan submitted annually for Government approval, thereby fixing in advance certain priorities, Sweden's Science Research Council has set up specialist committees for external priorities, such as ecology. On the other hand, the Research Councils can exercise an influence on where research takes place, deciding upon the location of investments and supervising the development of the teams. In Sweden for example, when a new professorship is to be established a process of consultation between the office of the Chancellor of the Universities and the Research Councils takes place[2].

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[1] *Science, Growth and Society - A New Perspective*, OECD, 1971.

Influence of this kind on the poles and location of research can only be brought to bear through close contacts with the university community. It is undeniable that scientific contracts exist and are much closer than in many European countries. It is, however, open to question whether the form these contracts take, among individuals and specialists regarded as scientists and abstracted from their institutional context, are of a kind to facilitate or to allow the introduction of a policy. The Research Councils did not seem to be able to concert their activity with agencies qualified to represent and commit the university as such.

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[2] But it is always the Crown which decides if a new Chair should be set up.

Part III

RESEARCH IN THE GOVERNMENT SECTOR

by
Gabriel DRILHON and Reuven ENOCH

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INTRODUCTION

Coming after the study of France, Germany and the United Kingdom, the survey of Belgium, the Netherlands, Norway, Sweden and Switzerland invites us to look for similarities and differences between these two groups of countries. Such a comparison must however be undertaken with great caution as regards the government sector, since the evidence shows far more clearly than with the other sectors that neither group of countries can by any means be regarded as a homogeneous unit. Not only does the size of these countries differ but also their national, historical, political, and administrative characteristics. For industry and university, respectively defined by a production function and an educational function regardless of the country considered, such national characteristics merely constitute an outer shell, whereas they are essential components in the case of government research agencies.

Table 1. **Performance and Funding of R & D in the Government Sector Relative to the National R-D Effort in Member Countries (1967)**

Country	Gross Nat. Expenditures on R & D $ Mil.	Gov't financed R & D		Gov't performed R & D		Performance as % of funding
		$ Mil.	%	$ Mil.	%	
Belgium	176.008	33.096	18.8	18.333	10.4	55.4
Netherlands	513.812	200.267	39.0	13.812* (113.139)	2.7* (22.0)	6.9* (56.1)
Norway	80.711	46.759	57.9	16.596	20.6	35.5
Sweden	336.090	135.840	41.1	47.748	14.5	35.1
Switzerland	303.950	64.117	21.1	19.293	6.3	30.1
France	2,506.750	1,340.615	53.5	804.742	32.1	60.0
Germany	2,084.324	835.700	41.3	106.225	5.1	12.7
United Kingdom	2,480.088	1,229.215	49.6	575.156	23.2	46.7

Source: International Survey of the Resources devoted to R & D in 1967 by OECD Member countries, *Statistical Tables and Notes*, Vol. 2, OECD, Paris, 1970, page 12.

* TNO being a legally independent organisation, has traditionally been classified as a private non-profit institution. Consequently the strictly-defined Government sector appears as a research-performer of marginal magnitude. By the nature of both the functions and structure of this organisation, it seems more appropriate to include it in the Government sector. The figures in parenthesis correspond to the broader definition, including TNO.

From the global figures given in Table 1 it is not possible to determine to what extent the importance of the Government sector in the five countries under study differs from that indicated in Volume I for France, Germany and the United Kingdom.[1] Before making any comparison, it is therefore first necessary to see how public action in the matter of research is organised by isolating its two main components: first, the individual characteristics of each country and, secondly, the various fields in which government action takes place. On the basis of such an analysis it will be possible to identify the problems arising in the Government sector with regard to both the management of research and its particular role within the system, and then to see just how far or near the problems in the five countries come to those of government research agencies in the three bigger European countries.

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[1] It must be emphasised that these figures are subject to considerable variation, depending on how much importance is attached to legal or functional criteria in classifying a given agency under some particular sector. This fact has already been pointed out in Volume I with reference to Germany and the United Kingdom and is clearly illustrated here by the case of the Netherlands.

Chapter I

THE ORGANISATION OF GOVERNMENT INTERVENTION IN THE MATTER OF RESEARCH[1]

It would be pointless to look for any logical, systematic approach stemming from some pre-established plan, in the organisation of government research activities, whether in the "smaller" or "bigger" European countries. Historical circumstances have invariably accounted for much of the pattern, and, as will be seen (Section 2), each field of intervention remains in a class by itself. As in France, Germany and the United Kingdom[2], however, in each of the countries studied certain leading features emerge which are sufficiently typical to be called "national patterns".

1. National patterns

A. *Belgium*

In Belgium, the government research sector is relatively limited; it includes about twenty establishments, the main function of which is public service. These establishments are managed and controlled by their various parent ministries. In fact, they have a certain autonomy in the choice of their research subjects which is made in consultation with advisory scientific councils, but their activities are oriented by the general options of the overall science policy budget, so that it is possible to keep under constant review the range, structure and balance of government-performed research and to apply effective criteria to the scrutiny of national objectives for priority decision making purposes. It must also be mentioned that the charters of these establishments as well as the status and career structure of their personnel were harmonised in 1965.

According to several scientists, the pre-occupation with the co-ordination and integration of state establishments into the overall system turned these establishments into "neatly organised" and easily manageable set-ups, but certainly also curtailed scientific originality by "bureaucratising" them to a considerable extent.

Mention should also be made of the extensive, though often invisible research undertaken by State-run public utility establishments (e.g. the Bibliothèque royale), the Institut royal du patrimoine artistique, the Musée royal de l'Afrique centrale, etc.). These establishments, which come under the Ministry of Education and Culture, can be assimilated to some extent to peripheral institutions.[3]

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[1] For a detailed description of how public intervention in the matter of research is organised see *Reviews of National Science Policy - Sweden* (OECD, 1964) - *Belgium* (OECD, 1966) - *Norway* (OECD, 1970) - *Switzerland* (OECD, 1971) - *The Netherlands* (OECD, Paris, 1973).

[2] Cf. Volume I, pp. 155-156.

It should also be mentioned that for some years the need has been felt to redefine the missions of the government research establishments according to the changing requirements of public service. The establishments themselves are conscious of the need for this updating which should be undertaken in the near future.

B. *Netherlands*

Government research activities in the Netherlands, on the other hand, are highly decentralised. Although the laboratories coming directly under the various ministries play a far from negligible role, they are considerably less important than specialised institutions endowed with a high degree of autonomy. The more fundamental research is essentially under the responsibility of ZWO[4], which is primarily a financing body, and the Netherlands Royal Academy of Science and Arts, whose institutes take the place of peripheral laboratories. More applied research comes under the responsibility of bodies such as the National Aeronautical and Space Laboratory (NLR) and above all TNO.

These institutions, all or most of whose resources are derived from the budget of the ministries concerned (often several ministries for the same body), are governed by boards which include scientists as well as representatives from any ministries concerned, other scientific agencies and the various economic or social sectors involved. In fact, the programmes are primarily initiated by research staff.

It should, moreover, be noted that internally these institutions are themselves highly decentralised, as is shown by the autonomy granted to various foundations of ZWO and the special TNO organisations.

C. *Norway*

In Norway, government intervention in the matter of research takes two leading forms: first, through the laboratories under the various ministries and, secondly, through the four research councils (NAVF, NTNF, NLVF and NFFR). As opposed to Belgium, government laboratories exclusively depend on their parent ministries for both finance and the establishment of research priorities. These laboratories retain, however, considerable autonomy as regards the realization of research projects.

The composition of the research councils is very similar to that of the boards which supervise the Netherlands' specialised institutions such as TNO or ZWO. NAVF and NLVF have practically no research laboratories of their own, but they play an important role in financing and co-ordinating research carried out in other sectors. NTNF, under which come [illegible] institutes, is granted more important resources than the two other [illegible] This fact has sometimes been criticised, but the efficiency of [illegible] nevertheless seems to justify the increasing resources which are allocated to it.

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[3] See Part II.

[4] See Part II.

D. *Sweden*

While government research agencies in the other countries devote a by no means negligible proportion of their work to more fundamental research, even when their prime objective is of an applied character, government controlled laboratories in Sweden usually[5] confine their activities to research of immediate and easily demonstratable value to their various sponsoring ministries. The rule is to leave everything other than very short-term research to university institutions. Similarly, industry is expected to assume full responsibility for applying any relevant basic knowledge.

In a sense, it is as if these establishments have consciously avoided overly ambitious scientific objectives, and have taken upon themselves to optimise application of available knowledge rather than generate new knowledge. In fact, it is hardly possible to trace specific decisions to that effect, nor does there seem to be a feeling of Government establishment engaging in second-rate, mediocre science, the State-employed science community seems to have adopted norms and performance-criteria, in which scientific excellence is subordinate to operational effectiveness.

E. *Switzerland*

The Confederation's limited intervention is due to Switzerland's federal structure, which provides a high degree of independance to the various cantons, and to an economic liberalism affirmed as an article of faith. Of the five countries under study, Switzerland is unquestionably the one in which government intervention is least extensive, although increased Federal responsibility is a tendency which may now be noted. While the trend is gradual and meets with considerable opposition, it exists.

Government research is performed by laboratories and institutes under the various Federal Departments. In this context should be noted the importance of Federal institutes which are administratively and financially dependent on the Federal Department of the Interior[6], but associated with the Federal Institute of Technology in Zürich for Scientific and Professional Aspects.

2. The fields of intervention

While the national patterns outlined above reflect the political, administrative, economic and sociological characteristics of each country, they fail to provide a complete picture of how government intervention in the matter of research is organised. True, as indicated in Volume I, such "exogenous" factors, as it were, come into play, but so do "endogenous" factors, such as the individual character of each field, etc.[7], which, transcending national traits, cause research agencies to possess certain similar if not identical features.

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[5] Defence research is however a very important exception. See chapter I, 2, A, d.

[6] It must be remembered that the Division of Science and Research of the Federal Department of the Interior is, within the Federal Government, responsible for the overall science policy.

[7] See Volume I, p. 149.

5

A. *The conventional fields*

a) *Agriculture*

Agriculture was the field in which a national pattern in the three "major" European countries[8] most clearly emerged, and it is perhaps here that the five countries under review prove to have the most in common.

In this respect, it is worthwhile to note that a few years ago, an international panel of experts[9] advanced the idea of a central National Research Institute, closely linked to the Ministry of Agriculture, as the basis for a proposed, widely applicable model. Such a semi-autonomous Institute was envisaged to assume the responsibility for implementation in the whole range of governmental agricultural research, and to derive its funds and research directives from the ordinary ministerial budgetary programme, the relevant research council (s), and some supplementary sources.

Whilst it is not surprising to see Belgium and Norway closely adhering to this pattern, it should be noted that in Switzerland agriculture is the only field where almost all research is conducted in federal institutes. True, Sweden conforms to the national pattern described above, since activities in the few laboratories directly under the Ministry of Agriculture are of a very applied character while most of research is carried out in institutes attached to the Swedish Agricultural College. Yet Sweden does not depart from the common pattern, in that this latter establishment comes under the Ministry of Agriculture. Lastly, a significant fact is that the Netherlands, after unsuccessfully trying to make agricultural research a TNO responsibility has assigned almost two-thirds of such activities to the institutes of the Ministry of Agriculture and Fisheries[10], which also sponsors the agricultural university at Wageningen.

The organisation of agricultural research in the countries under review is therefore marked by some degree of centralisation, much as in France. There is no institutional separation between more fundamental and more applied research as found in the United Kingdom at the policy level. In the latter country, moreover, it may be noted that the Dainton Report and the Rothschild Report, which discusses the future of Research Councils, were to some extent provoked by certain problems of the Agricultural Research Council.[11]

b) *Public health*

In contrast with agriculture a notably small volume of public health research is performed by government agencies in the five countries under consideration. While apart from Switzerland a few institutes under the responsible ministries admittedly exist, they are governed by predominantly service-oriented research directives and their main activities are of a consultative and regulatory nature, even when it has been found necessary to undertake more fundamental research intramurally.

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[8] Cf. Volume I, pp. 150-155.

[9] FAO, *Report on First Session of the Sub-panel of Experts on the Organisation and Administration of Agricultural Research*, Rome, 1965.

[10] However, consideration is being given to combining them in a single Foundation under the Ministry but with greater autonomy, which would be more in line with the general Netherlands pattern.

[11] Cf. *The Future of the Research Council System*, Report of a CSP Working Group under the Chairmanship of Sir Frederick Dainton, HMSO, Cmnd. 4814, page 1, paragraph 2, London, 1971. See Volume I, pp. 150-152.

Actually, research in this field, especially of the more fundamental character, is mainly performed in university laboratories and hospitals, and government intervention essentially consists in financing the research through such bodies as the FRSM in Belgium, the Sub-Council for Medicine of the NAVF in Norway, MFR in Sweden and the Swiss National Fund for Scientific Research.[12]

In the Netherlands, public health research is performed in four types of institutions: the establishments of the Ministry of Public Health and Environmental Hygiene; the institutes of the Health Research Organisation TNO; some institutes of the Royal Netherlands Academy of Sciences and Letters; university laboratories and hospitals where research is financed by FUNGO (the specialised foundation of ZWO). Moreover, there are two advisory bodies, the Medical Scientific Research Council sponsored by the Royal Academy, and the Council for Health Research sponsored by TNO. Such a dispersion of efforts seems to have been a serious obstacle to the development of a coherent research policy in the field.

The prevalence of university institutions in the performance of medical research has, of course, been pointed out earlier in the case of the three bigger European countries[13], but seems to be far more marked in the smaller countries where, apart from the Public Health Research Organisation TNO, there are no important institutions such as the laboratories of the Max-Planck-Gesellschaft in Germany, INSERM in France and the Medical Research Council Units in the United Kingdom.

c) *Industrial research*[14]

In view of the differences existing between the five countries as regards economic structure as well as basic attitudes towards Government/Industry relationships, as might be expected government intervention in this field varies considerably both as to pattern and scope from one country to another. Switzerland does no more than indirectly support industrial research by subsidising applied research through the Federal Commission for the Promotion of Scientific Research and provide general services to industry through the EMPA, a federal institution associated with the Federal Institute of Technology, Zurich and its Institute of Technical Physics. Belgium prefers to channel funds through IRSIA for research projects carried out by firms on a co-operative basis. In Sweden the STU finances research projects originating in firms or university laboratories while also providing an average 50 per cent of the resources of the 15 Branch Research Institutes[15]. In the Netherlands, the laboratories specialised in the various industrial branches are grouped together in the Organisation for Industrial Research TNO. Lastly, in Norway, in addition to a few laboratories under the various ministries, the NTNF plays a major role in industrial research, both through its own institutes and by participating in the financing of branch research institutes.

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[12] It should be noted that in Switzerland an important proportion of medical research is carried out in the laboratories of the big pharmaceutical firms.

[13] Cf. Volume I, pp. 156-158.

[14] See Part IV.

[15] The Swedish equivalent of the Research Associations in the United Kingdom, the "Centres techniques professionnels" in France and the AIF in Germany.

All such methods of intervention as the financing of projects carried out by firms, public or semi-public, laboratories and the financing of branch research institutes, are also used in different forms and varying degrees by France, Germany and the United Kingdom. Regardless of differences in national approaches and characteristics, it should, however, be noted that in dealing with industrial research the governments of all countries, both large and small, run into similar problems. In particular big firms already possessing considerable research potential clearly derive far greater benefit from such government aid[16] than small firms.

d) *Defence*

While military research is, of course, under the direct control of the Ministry of Defence in each country, the volume of such research and the way it is organised differs from one country to another. In Belgium all research is carried out in Ministry of Defence laboratories. The same is true of Norway, although here almost one fourth is financed from abroad particularly within the framework of NATO. In the Netherlands over one half of military research is carried out by the National Defence Organisation TNO (RVO-TNO), the remainder taking place in industry and in such establishments as the LEOK, which come directly under the Ministry of

Table 2. **Defence-Research in Five Smaller European Countries**

	Belgium (1968)	The Netherlands (1969)	Norway (1969)	Sweden (1969)	Switzerland (1967)
Total expenditure on defence research (Mil. US $)	2.0	11.0	4.0	79.0	7.5*
Defence-research as % of total public R & D expenditures	2	2	7	31	26**
Defence-research as % of national defence budget	0.3	1.3	1.3	10.0	2.5
% of total defence-research performed by government establishment	100	85***	95	25	25

* Based on data contained in the OECD Swiss Review of National Science Policy. The figures should be considered as rough estimates in view of the fact that, as stated in the Review (OECD, Paris, 1971) " statistics are still rare and largely scattered in nature ".

** Of Federal R & D expenditures.

*** Includes TNO-RVO (performing more than 50 % of the total defence research), as well as establishments run directly by the State.

Source. Research and Development in OECD Member Countries - Trends and Objectives, OECD (to be published).

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[16] This is perhaps less marked in Norway where the disparity between firms is smaller than in the four other countries studied.

Defence. In Switzerland the federal institutes of the Armaments Group of the Federal Military Department perform only 25 per cent of defence research, 75 per cent being carried out in industrial laboratories and, to a much lesser extent, in some university laboratories.

While in these latter four countries the amount of military research, both in relative and absolute terms, is much more limited than that in the three bigger European countries,[17] Sweden's own conception of its policy of neutrality implies an independent defence capability, of which a strong R & D effort is a necessary component. Military research thus accounts for almost one third of government R & D expenditure. About one-fourth of such research is carried out in Ministry of Defence establishments, and the remainder in the laboratories of public or private industrial firms.

B. *The new fields*

A common feature of new fields is that they belong to "big science" and are thus extremely costly; furthermore the costs steadily increase as they become scientifically and technologically more advanced.[18] In these fields the smaller countries, whose financial resources and scientific personnel are limited, not unexpectedly have followed paths other than those selected by the three bigger European countries.

It is for instance significant that in none of the countries concerned is any such overall oceanological programme found as in the three "major" European countries.[19]. While research in this field is by no means insignificant, especially in Norway and in the Netherlands where the sea is basic to the economy and the environment, it is shared between various agencies and authorities. In other words, oceanology in these countries is still the sum of research activities undertaken on the many aspects of the marine environment instead of being regarded as a separate field of science standing on its own. It should be noted, however, that in the Netherlands an important step forward in this direction was taken by creating an Interministerial Committee for Oceanography. A similar measure has recently been taken in Norway with the establishment by NAVF of a Committee for Oceanographic Research with a view to coordinating national— and Norwegian participation in international— activities in this field.

a) *Nuclear energy*

Nuclear research as organised in the five countries surveyed is, institutionally speaking, split to some extent between research of the more fundamental type, notably on high energy physics, and applied research in nuclear energy. Fundamental research is primarily performed in university laboratories and usually is co-ordinated as well as financed by such agencies as the IISN in Belgium, FOM (one of the ZWO foundations) in the Netherlands and AFR in Sweden, which play a role much like that of the Nuclear Physics Board of the Science Research Council in the United Kingdom.[20]

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[17] See Table 2.

[18] Cf. Volume I, pp. 160-161.

[19] Cf. Volume I, pp. 170-173.

[20] France adopted a similar system a year ago, with the National Institute of Nuclear Physics and Physics of Particles.

The Nuclear Energy Centre (CEN)[21] in Belgium, the Netherlands Centre for Reactor Research (RCN) and the Atomic Research Institute in Norway are mainly concerned with applications of nuclear energy (excluding military applications) although they also undertake a fairly substantial amount of more fundamental research needed for developing such applications. In the case of Switzerland and Sweden the organisation of research merits more detailed examination in that it illustrates both the problems and current trends.

In Switzerland the role of the Confederation at first merely consisted in financing fundamental research carried out in university laboratories, while in 1955 a group of private firms founded a company called the Reaktor AG to develop, build and operate a reactor for industrial purposes. In 1960, these firms, facing severe financial problems, having no returns on their investment and failing to agree on the direction of research, refused to go on financing the venture. The Confederation therefore had to take over the research centre which then received its present status as a federal institute associated with the Federal Institute of Technology, Zürich. In 1961 a number of firms established a national company, the NGA, the basis being a reactor project, which is moreover financed up to 50 per cent by the Confederation. This project could not be brought to a successful conclusion due to technical and financial difficulties.

By creating AB Atomenergi in 1947, Sweden started its work in the nuclear energy field in a purposeful way. The aim was, from the outset, to gradually build up a reactor industry which, independent of foreign licences, could acquire a capacity not only to manufacture reactor components and reactor fuel, but also to design and construct complete nuclear power stations. AB Atomenergi was originally a semi-public company, with the Government as the majority shareholder. The company's successful R & D soon made Sweden the smallest of the handful of countries which have developed a reactor system to the stage where it can be marketed commercially, and the only Western country which has developed light-water reactor systems without licence from the United States. In connection with the gradual commercialisation of the nuclear-power field, the company's tasks have likewise changed: AB Atomenergi's activities are now concentrated on R & D in close co-operation with industry and the power utilities, and the latter two parties have taken over responsibility for the design and construction of power producting reactors. The change was concretely manifested in January 1969, when ASEA-ATOM established on a fifty-fifty basis by the Government and ASEA, started its activities. Later the same year the Government took over all the shares of the previously semi-public AB Atomenergi enterprise.

It is striking, therefore, to see such different examples as Switzerland and Sweden both offering such a clear illustration of two characteristic aspects of this field, that is, a tendency to move from the research stage to that of industrialisation as in the bigger European countries— the need for the State to play a key role. This second point is obviously related to the extent of the financial outlays and risks involved. In view of the limited resources, the countries studied have remained aloof from military applications, which in 1968 accounted for about half of the nuclear effort in France and more than one third of that in the United Kingdom.[22]

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[21] CEN is a public utility private institution but it is considered as belonging to the Government sector since most of its resources come from public funds.

For the same reason, the countries under consideration have directed their national efforts towards international co-operation to a far greater extent than the three bigger European countries. Participation in international organisations account for 15 to 20 per cent or national R & D expenditure in Switzerland and Sweden, about 30 per cent in Norway and the Netherlands and 50 per cent in Belgium. Moreover, with the exception of Sweden, these countries have at least one international centre on their territory: EURATOM has laboratories at Petten in the Netherlands and the Central Nuclear Measurements Bureau at Geel in Belgium, the Nuclear Energy Agency (previously ENEA) sponsors and operates an international project at Halden in Norway, the headquarters of EUROCHEMIC are at Mol in Belgium, while the CERN installations are located at Meyrin, near Geneva in Switzerland. It should also be mentioned that nuclear energy is the field where co-operation between Scandinavian countries is most developed.

Although research efforts in this field are limited to civil applications of nuclear energy and primary importance is attached to international co-operation, the burden thus laid on the five countries[23] is extremely heavy, too heavy in fact, in the opinion of many research scientists working in other fields. They are perhaps to a certain extent bound by the commitments entered into during the period following the Second World War, when the tendency was to underestimate the time and expenditure needed in applying nuclear energy and when national prestige frequently carried more weight than economic considerations.

b) *Aeronautics and space*

As there is no important aircraft industry in Belgium, Norway or Switzerland it is hardly surprising that research should be so limited in these three countries; what there is of it is generally carried out in the Defence Ministry establishments for the purpose of testing and using aircraft purchased from other countries. In the Netherlands, research by the National Aeronautics and Space Laboratory (NIVR) is undertaken on a slightly larger scale but is still relatively limited. Sweden is in an entirely different position from the other countries reviewed, since in line with its policy of total independence in defence matters, it has developed its own aircraft industry, one essentially geared to military requirements most of the research is in the hands of Swedish Aeronautics Institute (FFA), which is under the Ministry of Defence.

None of the countries in question has any major national space-research programme comparable with that of Germany, France of the United Kingdom. Almost all such research is performed under the heading of international co-operation, bilateral, (mainly with the United States) and multilateral (mainly ESRO and ELDO); even in the Netherlands the apparent leading aim of the NIVR lies in helping Netherlands industry to share more fully in the activities of these international bodies.[24]

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[22] See Volume I, pp. 163-165.

[23] If R and D activities are listed in descending order of allocated expenditure, nuclear research will be seen to come second in the Netherlands and Switzerland, third in Belgium and Sweden and fourth in Norway. Source: *Research and Development in OECD Member Countries - Trends and Objectives*, OECD (to be published).

3. Conclusion

As might be expected, it is in the new fields that the five countries most widely differ from their three bigger European counterparts. In is thus striking to find that the governments of all five countries have acted in the same conventional fields as those of Germany, France and the United Kingdom: agriculture, health, industrial research, defence. Furthermore, the trends and problems in these areas prove to be the same whatever the size of the country: centralisation to some extent of agricultural research, predominance of university laboratories and hospitals in the matter of health, difficulty of drawing actual benefit from Government research aid for small firms, to mention but three examples. In the new fields, however, the differences are very marked, and the newer the field the greater the difference. True, the governments of the five countries have intervened in the matter of nuclear energy and the same institutional division exists between more fundamental research and more applied research, but the scale of international co-operation in nuclear matters is worthy of note. Space research ranks as a much less important undertaking than in the three bigger European countries and all activity in this field is confined to international co-operative ventures. Finally, oceanology has not yet been tackled as a field of science in its own right.

These differences of course are due to the unescapable fact that the smaller countries have limited financial resources and scientific personnel, but owing to the importance of the new fields and the questions these raise for the three bigger European countries, especially in the Government sector, such differences have considerably affected the role of government research agencies and the problems with which they are faced.

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[24] Although Norway is not a member of ESRO, it has participated in certain ESRO activities, mainly by assisting in the launching of ESRO sounding rockets from Norwegian soil and in the operation of two telemetry stations for data reception from ESRO satellites.

Chapter II

ROLE AND PROBLEMS OF GOVERNMENT RESEARCH AGENCIES

Just as the structure of Government research action can be analysed in terms of national patterns and of factors which depend on the nature of the individual fields, so can the problems of the government research establishment agencies be studied from two aspects: as part of the public sector they are governed by administrative regulations little suited to research management and as research agencies they are part of a country's research system, in which they play a special role.

1. Problems of research management in Government establishment

It should be noted that, in this respect, the Government sectors of smaller countries seem to have more in common with their counterparts in bigger countries, than they have with the other research-performing sectors within their own national systems. Notwithstanding this basic similarity, however, certain problems tend to take a particularly acute form in smaller countries.

A. *Problems of financing*

There seem to exist three basic incompatibilities between the rigidity of governmental budgeting, and the prerequisites to efficient financial management of R & D activities:

- *i)* Central control of the financial management of Government research establishments is extremely strict to the extent that it decides not only balance of expenditure between various budget-headings (staff, equipment, etc.), but often also the actual pattern of expenditure within each major category. This severely limits *manœuverability* at institute/department project level.
- *ii)* The Administration exerts pressures for all expenditure to be planned in minutest detail, and accurately estimated in advance. This tends to curtail the extent of *flexibility* that is absolutely essential in the light of the uncertainties inherent in any scientific investigation.
- *iii)* Traditionally, governmental budgeting is done on an annual basis. Government research-establishments are thus denied financial *stability*, and projects (particularly in fundamental research, where short-term results are less demonstrable) run the risk of being discontinued.

Government establishments in the countries surveyed, as well as in the three bigger European countries, have found different ways of augmenting their manœuverability. In many instances, an agreement is formally reached with the ministerial accounting department, whereby directors of institutes are authorised to transfer funds within certain budgetary headings, but not across them. Another fairly standard procedure is to grant the institute-management absolute decision-power over financial commitments not exceeding a certain magnitude. Regardless of such formal adaptions, however, it has become common practice for institute directors to keep a certain informal reserve of funds under their close personal supervision, which they redistribute— at their own discretion— among the various departments. Such "domestic emergency funds" were in operation in all the establishments visited. In several cases, they were said to have provided the initial support for unanticipated intramurally-developed research proposals, when no other funds could be raised.

Informal links between the single establishment and the appropriate ministerial authorities seem to play an important role in this respect: it was repeatedly pointed out by institute directors, that whenever an urgent need arises for unexpected transfers of funds, or for the authorisation of an interim budget, they resort to personal contact with colleagues at the Bureau of the Budget. Owing to the relatively small size of governmental research set-ups in these countries, and to the aforementioned low rate of personal mobility, an "old boy" system tends to come into being and offset some of the detrimental effects of bureaucratic rigidity.

Similarly, most establishments have devised means of partly regaining their flexibility. This may be achieved by systematically developing extra-governmental sources of finance, which can be channelled to additional aid where it is especially needed, or used to provide the necessary groundwork in a new, or rapidly-expanding field of research.

There is, however, serious controversy regarding the "external sources" issue; no agreement has been reached as to whether government establishments should have any income at all other than through their regular budget, what the optimal proportion of such income should be in an establishment's overall turnover, and from which of the available extra-governmental sources a government-establishment should be allowed to derive it.

In Switzerland, Government research establishments are not allowed, as a rule, to dispose of any funds other than those allotted to them directly by their respective parent-ministries. Even occasional income from charges or sale of by-products is automatically transferred by the individual establishment to the Federal Department concerned. In Sweden, on the other hand, establishments are encouraged to acquire research contracts from private sponsors. Moreover, research-teams and individual government-employed scientists are permitted to apply for research-council grants and to devote them to projects that need not be directly linked to any of the establishment's objectives. In the Netherlands, (particularly in TNO's specialised organisations, but also in the Government sector proper), some contract work is regarded as an integral part of every institute's ordinary budget. A satisfactory growth rate of contract performance has become in some instances a necessary condition for any increase in governmental subsidies.

Measures are also taken to guarantee a greater measure of continuity by extending the range of R & D planning. Often, establishments now have long-term (range: 10 years), "outline-programmes", centred on a few major "gravity points", and detailed research plans for a time span of up to five years. Belgium's Centre of Nuclear Studies has recently adopted the following planning method, which illustrates our point: An ad hoc Enlarged Programm Committee is responsible for the preparation of a quinquennial plan, which is thoroughly reviewed each year, thus always retaining a planning range of five years. According to the directives laid down in this long-range plan, the Centre's Administrative Council submits each year to the Ministry of Economic Affairs its proposed annual programme and requested budget.

Since the annual basis of budgeting cannot be abandoned altogether, it would seem advisable to give the single establishments a greater degree of independence, by basing their yearly allotments on specific projects within their respective terms of reference.

While the small size of the countries in question does much to promote closer personal ties with responsible scientific and administrative staff and thus makes it easier to overcome the rigidities of financing procedure, despite the devices and expedients used in daily practice the problem remains a serious one and is basically the same in all countries, whatever their size.[1] It is moreover significant that the issue should be far less acute in such institutions as TNO, which are much more autonomous and have wide manœuverability.

B. *Staffing problems*

The question of staffing a research establishment may be regarded as the supreme problem in organising research. Government research establishments in all five countries reported having considerable difficulties in the recruitment of high quality personnel. In 1966, the OECD Advisory Group on Fundamental Research observed: "If Governments are to attract to their own laboratories fundamental research scientists of quality of the level of those entering university or industrial research, pay and conditions of work must be at a competitive level, and superannuation and other schemes devised in a flexible manner to encourage a substantial and easy flow of research workers between laboratories, universities and industry."[2] In recent years, Governments have introduced more generous pay, particularly at the low levels of the research ladder, but as a rule, scientists in the public sector are still required to make a considerable financial sacrifice.

In Belgium, the Centre national de recherche métallurgique adopted an original pay structure, guaranteeing to junior scientific personnel— during the first ten years of employment— absolute comparability to salaries and fringe benefits with scientists employed in industry. The operation of such a flexible scheme, which satisfactorily solved the Centre's recruitment problems, was facilitated by the fact that, in spite of heavy State interest in the management of the Centre (via IRSIA) it has the legally autonomous state of a private organisation. For obvious reasons, it would not be possible for a State establishment proper, accountable to a parent Ministry which governs its personnel policy, and restricted by Civil Service rules and regulations, to be as adaptable. A similar approach is called for whenever practicable (e.g. in the Netherlands, where TNO's legally "independent" Organisations attribute their severe difficulties in recruiting competent staff to the direct competition of industry's attractive Big Five).

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[1] Cf. Volume I.

[2] *Fundamental Research and the Policies of Governments*, OECD, Paris, 1966, p. 53.

The basic constraint on recruitment to Government scientific employment is the lack of opportunities to use premiums for quality, so as to make it sufficiently attractive, both in fact and in the minds of potential recruits, for first-rate personnel. The attraction of job security, on the appeal of which recruitment to non-scientific employment relies to a great extent, is unlikely to play a large part in deciding the attractiveness of a particular scientific appointment, especially to top-calibre men, for whom the value of the scientific work being done, rather than mere financial or security-of-tenure considerations, is the decisive criterion. "Good places draw good men", asserted one senior scientific officer, "and this is as true in the Government sector as it is in the universities and in industry". "Good" in this context has two aspects: technical competence, and singularly "worthwhile" fields of research. The most acute recruitment problems are encountered by the many State establishments that can neither claim special innovative "worthwhileness" in the science-for-its-own sake sense, nor appeal to potential recruits by a record of scientific excellence or by the "glamour" of ultra-modern apparatus and exceedingly advanced methods.

These establishments (exemplified in all five countries by some service-oriented agricultural and veterinary research stations, and to a lesser extent, also by public institutes for health research), often attract a rather high proportion of second-rate scientists. An alarmed research director commented: "Unless radical measures are taken, Government research establishments will inevitably drift toward scientific mediocrity; in many areas they seem to have already run down the way of intellectual decline". While this generalised observation is, perhaps, stated in excessively categorical terms, it certainly reflects a widespread anxiety, about governmental research establishments being transformed into "havens for second-rate scientists."[3] The problem is obviously much more difficult in the countries under review than in the three bigger European countries, since owing to the far smaller number of scientific personnel available for the same tasks second and even third-rate scientists must sooner be relied upon.

However, any attempt at explaining the present intellectual stagnation of certain governmental institutes solely or chiefly by the allegedly poor quality of their recent recruits must be regarded either as a gross over-simplification, or as the expression of a strong vested interest.

A further major deterrent to safeguarding high standards of scientific performance in governmental establishments, is the *imbalance in staff mobility,* and the resulting *unhealthy age-distribution of scientists in the* Government sector. The pay structure and promotion patterns in Government-run establishments militate against mobility, especially among staff in the intermediate and senior levels. During the first years of their professional career, junior scientists show considerable intra and inter-sectoral mobility. Many of these scientists, particularly those who first join the State establishments as doctoral or post-doctoral fellows, tend to regard their first appointments as an opportunity of complementing their academic training by highly-diversified, practical experience. It is, therefore, typical of Government research centres that they experience a continuous turnover of young, often highly competent scientists, whom the management could certainly regard as a substantial asset, were it not for the overtly-admitted transitional and temporary nature of their association. The director of a large government-establishment has found his scientific staff to be dominated by two "sub centres"— "The Young Clique", a constantly changing group of scientists, typically under the age of 30, moving in and out within the first five years of employment, and "The Veterans Club", a solid group of employees, who have been with the organisation ever since its establishment.

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[3] See Volume I, p. 176.

There is no direct evidence that young scientists who take up permanent appointments in the public sector are less competent than their colleagues staying on in the universities, or joining industry. This may be and is, indeed, suspected to be so, as the following comment by a Government-employed scientist suggests: "If it's primarily money, or technological fascination, a competent young researcher is after, he will most probably join industry; if he looks for freedom to do what he likes— he will prefer the university environment. If he chooses a job in the Government sector— either because it seems to offer some authority, or for the attractions of job security and more favourable pension rights— then I cannot help suspecting him of lacking competence, and of having adopted a low level of professional aspirations." This opinion can certainly not be dismissed out of hand, but the following qualifications are called for:

i) In the last decades the shortage of scientifically-trained personnel caused a situation where the individual researcher normally had a wide range of jobs to choose from. This has changed considerably in recent years, and nowadays even highly competent scientists are often forced to engage in "job-hunting" and settle for an appointment which is not entirely to their liking.

ii) While one can clearly trace, among young scientists, a general disinclination to take up permanent employment in small and peripheral State-establishments, the situation is profoundly different in the metropolitan institutes, particularly in their better sections.

iii) In some instances, competent young scientists tend to enter the Government sector, if only for a few years, out of genuine patriotism, truly believing that they can best serve what they regard as the "national scientific interest" by joining a State establishment.

iv) The scientists' alleged fear of, indeed aversion to, being "bureaucratised" and soon falling into the "trap" of administrative appointments has often been presented as the main obstacle to more effective recruitment into Government Research Establishments. In this respect too, things have changed: the Scientific Civil Service, in all five countries, is nowadays believed to offer a degree of freedom to do one's work, which is usually not matched in industry. Furthermore, interest in science policy making and research administration seems to have appreciably risen among scientifically trained personnel, newly joining the labour force. Many of these younger force scientists consider work at the bench in a Government-run institute to be the best background for an ultimate career in policy making.

v) Finally, we should not forget the competent young scientists whose specific interests happen to lie in fields of research where the Government is the only, or the leading employer.

Objective evidence seems to indicate that for several years, Government research establishments in all five countries have had, as a rule, an adequate supply of scientifically trained personnel (in terms both of quantity and quality). Yet, at the same time, we find throughout the governmental sector strikingly widespread dissatisfaction with the allegedly recurrent failure to recruit really first-rate staff. In many Government establishments, the difficulties thus wrongly attributed to recruitment failures appear to originate from the following inter-related problem areas.

a) *Deficiencies in their absorptive mechanisms*

Having been unable to effectively check or counteract the massive loss of highly competent personnel during the first few years of employment, research-establishments in the government sector have an exceptionally high turnover rate. This symptomatic one-way movement of staff tends to impair the consolidation of an esprit-de-corps and the formation of permanent research teams. It also undermines any attempt at rationally planning the research effort over a reasonable period, and impedes the efficient execution of programmes that depend to a large extent on continuity. (Surprisingly enough, it was repeatedly pointed out, in two of the countries surveyed, that the constant drain from government-establishments to the other research sectors is, and should be, regarded as a phenomenon which is not only tolerable, but indeed desirable from a "national scientific interest" viewpoint, inasmuch as it provides industry and the universities with a continuous feed of well-trained manpower).

b) *Lack of mobility at the intermediate and senior levels*

As was noted earlier, the lack of opportunities to use premiums on quality constitutes a major obstacle to the absorption of competent personnel in Government research establishments. At the same time, the lack of opportunities to use sanctions against poor performance (because of the high security of tenure), tends to result in undue retention of relatively incompetent staff in the higher echelons.[4] The typical age-distribution of government employed scientists in all five countries, shows the same unhealthy anomaly: staff is either of almost uniform age (where massive recruitment had been undertaken during the establishment's early take-off period), or heavily concentrated in a few discontinuous age-groups (where there had been several stages of expansion in the establishment's history). The natural tendency of scientists to gradually lose their creativity and penetration, and the devitalising effects of inertia become more harmful in cases of such "collective ageing".

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[4] Mention should, however, be made of the exceptional case of a Swedish institute where a considerable proportion of the staff was disbanded in order to renovate this institute.

c) *Sub-optimal staff utilisation*

If a research establishment is to retain its scientific dynamism, it must not only carefully select (and effectively absorb) creative new recruits, and retire (or whenever possible usefully redeploy) incompetent staff. It must also find ways of sustaining a consistently satisfactory standard of performance among its permanent employees. It is one problem to get (or, for that matter to retain) the best available research workers. It is quite another problem to best utilise the potential of the staff existing.

There is no panacea to guide research directors aiming at optimal utilisation of their scientific staff. In recent years, however, the relationship between research environment and creativity has been thoroughly investigated. Even though most of these investigations fall short of offering any systematic explanation of the creativity phenomenon, they have certainly yielded valuable knowledge on some "environmental" circumstances which are conducive to creativity and others which are detrimental to it. Some of this knowledge has important personnel-related implications that should, indeed, be taken into consideration when conditions of employment are determined or reviewed. For example, it has long been established that freedom to publish and access to the international community are essential. Again, it has been found that even in the context of strictly defined mission-oriented research, scientists should not be deprived of the right and freedom to question the data, the procedure, or the interpretation, so as to allow for reciprocal fertilisation between basic and applied aspects of an investigation.

C. *Relations with other research establishments*[5]

a) *Lack of competitive challenge*

Government research establishments are— as indeed any type of State enterprise— buffered from acute pressures for survival. Irrespective of their productivity, they may under normal circumstances take for granted not only mere survival, but also semi-guaranteed growth. The protection from external stresses offers Government establishments some obvious advantages. If, however, the relative protection turns into absolute freedom from competitive pressures, then internal performance standards are bound to deteriorate. This trend is all the more dangerous in small countries where a particular establishment may well be the only one (in the Government sector, or even in the national research system) performing research in some specific area, thus becoming especially vulnerable to the debilitating effects of unchallenged existence. The establishment's level of satisfaction will gradually go down, and manifestations of inefficiency be more readily tolerated. This may, perhaps, account for the survival of anachronistic organisational structures in the system of government research and explain why many Government research establishments lag behind in the application of modern optimisation techniques.

b) *Parochial isolationism*

Close reciprocal relations between Government establishments and those of the other research sectors, are known to be of paramount importance. Yet, in actual fact such relations have not fully developed in any of the systems surveyed. The inclination towards parochial isolationism may be attributed in part to the freedom from competitive challenge, which inevitably reduces the urge to follow external developments systematically. The situation is sometimes aggravated by inadequate information services (both within the governmental sector and between sectors), so that a group working in a particular area is often unaware that another team is engaged in similar work. Even when information is available, and genuine interest in collaboration does exist, Government establishments may be handicapped by bureaucratic rigidities, of which the financial inflexibilities are just one aspect: various official authorisations must be obtained, the provisions of each co-operation scheme must be formally specified, in advance, in a contractual instrument, etc.

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[5] The problems mentioned under this heading are common to other small countries. See *Reviews of National Science Policy - Iceland*, OECD, Paris, 1972.

2. The Government sector in the research system

When, in the five countries, the question is put why a certain type of research is carried out in a government agency, the same reason for the existence of these establishments is given as in the three "major" European countries.[6] In other words, the "raison d'être" is the same one regardless of the country being examined: "in the first place there was a job to be done which included research; in the second place this research could not be carried out, or at least not so efficiently and rapidly, by other means."[7] Beyond this basic similarity, important differences are found, depending on the weight attached to the first or to the second element of this "raison d'être", to the positive or negative aspect.

By deliberately adopting a policy which especially favoured the new fields, three bigger European countries have, since the last war, attached more weight to the positive aspect. It is mainly owing to the political importance of these fields and because they belong to big science that these countries have entrused the leading role in implementing national nuclear, space and oceanological policies to government agencies. It is hardly surprising that these establishments should be precisely those most threatened by obsolencence, not so much through the fault of the establishments themselves as owing to somewhat over ambitious policies, often established on an excessively short-term basis, which are out of step with the rapid strides made in the new fields. Establishments working in conventional areas which are less threatened in this respect owing to the more permanent nature of their tasks, while admittedly they have not enjoyed the favours bestowed on the more privileged instruments of major political objectives, have often enjoyed some reflected glory and learned some profitable lessons from them; they have, as it were, jumped on to the nuclear energy or space research "bandwagon".

The five countries, with only limited resources at their disposal have not left the role of prime scientific mover to the new fields: they have no major national space or oceanological programmes and this involvement in the nuclear field, even though relatively extensive, appears to be something which they submit to rather than wholeheartedly accept. On the other hand, government intervention covers as wide a spectrum of conventional fields as in the "major" countries since, to quote a senior science policy executive... "when it comes to government performed research, a small country has the same number of problems as bigger countries, and its governmental research set-up must maintain a spectrum of capabilities as broad as that of bigger countries, different only in magnitude and intensity."

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[6] Cf. Volume I, pp. 186-189.
[7] Cf. Volume I, p. 189.

In these countries a day-to-day pragmatic approach, one mainly and with some measure of success oriented towards economic development, as a rule seems to have carried greater weight than major policy objectives. Often such a pragmatic attitude may even have taken the place of policy, to judge from the following comment: "had there been a deliberate decision assigning to the government sector special, strategically important, fields of science or clearly defining the expected orientation of its research activity, we would now know where we are going." In the absence of such a definition, government research establishments in all five countries, find themselves pursuing a "mixed salad" type of research programme, covering fields that have been neglected by industry and universities. The government sector which to quote a typical remark by a government employed scientist— "is there to do whatever the others are not doing"— has thus become, at least in its research-performing capacity, a minor partner in the national system which is dominated by giant corporations and academically free universities.

Government research establishments must bear the responsibility for the support of R & D in relation to general public welfare and social considerations without themselves having a genuine choice; rather than consistently following a coherent programme of their own, they must often respond to the changing priorities adopted by industry and the universities in order to satisfy urgent needs. Examples are numerous: Switzerland's Institute of Reactor Research had to be taken over by the Confederation when industry refused to sustain its subsidies; Belgium's Royal Institute of Meteorology had to introduce a great deal of theoretical research and to engage in the supervision of doctoral students because the subject was not taught in any of the Belgian universities; Sweden's Institute of Agricultural Engineering had to perform much unanticipated development work— up to and even beyond the prototype phase— because some of the machinery it designed was not regarded by industry as sufficiently "ripe" for commercialisation.

The impression of specialising only in subjects which others have left to one side leads to very strong feelings of discontent among scientists in Government agencies, and these feelings are aggravated as the absence of a policy in assigning missions has repercussions on the formulation of research objectives, as illustrated by the remarks of a scientist: "due to our small dimensions we are perhaps in a position to know better than our counterparts in bigger countries what should be done, but we do not always appear to be able to agree on the best course of action." In these countries all action seems subordinate to a wide consensus of all people involved and this sometimes leads to a certain stagnation.[8] Moreover, such disagreement is primarily related to activities which transcend the routine, science-oriented, work; the less demonstrable the link is between a research project undertaken by a government laboratory and the overall mission of its parent agency, the more intense disagreement on the character, magnitude and urgency of the needed effort is likely to become.

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[8] See Part I.

Owing to these circumstances, in the five countries considered, Government laboratories not unexpectedly suffer mainly from the feeling that they have been systematically relegated to the role of "poor relations" in the system, and can only feed on the research crumbs left by their pampered industrial and university counterparts. In the three bigger European countries establishments working in the new fields are, when their raison d'être is challenged, in rather the same position as an aristocrat who dislikes the idea of reverting to mere commoner status, while in the five countries under consideration Government research agencies are rather in the position of a serf aspiring to full citizenship; in the first case the problem must be ascribed to a short-sighted policy, and in the second to the absence of any policy.

Part IV

INDUSTRY, SCIENCE, UNIVERSITY

by
Salomon WALD

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INTRODUCTION

The following pages try to explore and compare the industry-science interface in Belgium, the Netherlands, Norway, Sweden and Switzerland. The main sources of this study are visits to industry, university and government paid during 1971.

Thirty industrial companies using science and advanced technologies were visited, 8 in the Netherlands and Switzerland respectively, 6 in Sweden, 4 in Belgium and Norway respectively. Of these companies, 15 are among the 25 biggest Corporations— 5 in each country— which are mentioned in table 2.

In nearly all the companies, the people interviewed were the research directors or their deputies, and often some of their collaborators, and occasionally other senior staff members. In the higher education sector, professors and assistants from various fields of science and engineering have been visited. Some of them were faculty or university heads, and many of them knew industry well. They were teaching in 18 different institutes of higher education, including almost all the important technical universities of the five countries. Civil servants in the ministries responsible for science, higher education, economic or industrial affairs and defence gave an account of government experience. The point of view of other public or semi-public organisations, such as Academies of Science or Manufacturers' Assocations, were also taken into account.

Although the people interviewed do not represent a "sample" in a formal statistical sense, their number, variety and competence should guarantee that a description of the research climate in their countries which is based on their experience, is fairly accurate.

If one compares the industry-science interface of France, Germany and the United Kingdom to that of the five countries which are the subject of this Volume, the latter appear to be different in three respects: firstly, their industry, with the exception of Norway, has a relatively bigger share in the national research system. In Holland and Switzerland, multinational company research has had a certain scientific impact by creating centres of excellence and covering new fields, comparable to the peripheral research system in France (CNRS) or Germany (Max-Planck Institutes). Secondly, in the Netherlands, Norway, Sweden and Switzerland, industrial technologies developed in a very favourable educational environment thanks to the quality and industrial purpose of the technical universities. Thirdly and finally, a multiplicity of public institutions and policies for applied research clearly signalised that application was a major national priority. Although this holds true, in varying degrees, for all five countries, effort and success in this respect are most noticeable in Belgium and Norway, at least in relation to the initial industrial strength of these two countries.

Not all five countries have developed the same set of strong points in their industry-science interface, though all these strong points can be found in more than one country. This Part will elaborate on these three ways in which five countries, taken as a whole, differ from big countries in Europe.

If, in fact, the system of research in smaller countries has shown more success and originality than that of big countries, it was in the industrial application of science and technology, rather than in the organisation of research in university or government laboratories. A general observation may summarize some of the explanations which follow.

The deepest reason for success and originality in the application of science was probably a relative weakness of traditions which strictly separated "fundamental" from "applied" research. Institutionally and philosophically, the borderline between them in many small countries was less old, less clear or less infringible than in the others.

The universities, especially the technical universities, performed industrially useful research, and some of industry's own research was so original and "fundamental" that it advanced the frontiers of science, yet neither side considered that it transgressed its own role. This is not to imply that more "classical" attitudes were absent in small countries: all the traditions which opposed «fundamental», «pure», «independent» research to «applied», «oriented» research— insinuating that the latter was less dignified— were to be found there as well. But is seems that at least some of the best scientists were ready to ignore the "border" between the two and to become "fundamental" in those fields of science which were industrially useful and applicable or, if they started at the fundamental end of the research spectrum, they interested themselves actively in possible applications and sales-prospects.

Significant for this scientific atmosphere is the remark of a university rector and professor of physics who helped to develop industrial innovations in one the five countries: "If I could not apply my research, I would reproach to myself that I was not fundamental enough." Probably, this sort of research motivation in industry and university helped some of the five countries to harness their limited scientific and technological resources.

By at least partly concentrating research in those sectors which could be— and which often were— technologically rewarding, industry and university managed, so to speak, to kill two birds with one stone: they developed successful industrial technologies and maintained an international level of quality in research. Of course, other factors played a role in this double success, especially as far as the quality of research is concerned. Neither molecular biology in Sweden, nor astronomy in Holland was particularly indebted to industry, to mention only two fundamental research sectors in which small countries have achieved a good reputation. It is not suggested here that the high quality of research in small countries was mainly due to the latter's links with advanced technology and industry, but there are enough signs that such links existed and that they were more relevant to the science of smaller than to that of bigger countries: some Swedish Nobel-prize winners graduated as engineers, at least three of Switzerland's seven science Nobel-prize winners received the award for work performed in, or in collaboration with industry, and in the Netherlands, many of the scientific publications in physics are still coming from industry.

However, the industry-university-science interface seems to be changing in the five countries. The reasons of past success appear clearer today than they would have twenty years ago, though it is not clear where the changes in the science-technology interface will lead to, or even whether they are deep or lasting.

It is possible that "killing two birds with one stone" will become more difficult. Some researchers in industry believe that in the more rewarding research fields of the past, there are not many birds left to kill. Increasing research costs in and outside industry and an apparent levelling-off of science-based innovations, for example in pharmaceutical or chemical fields, seem to give credit to such convictions.

In the future, the synthesis of a new compound is less likely simultaneously to cut down the costs of an industrially important chemical and to recommend one or two scientists for a Nobel prize, as was true of the years during which most synthetic vitamins were discovered. As far as new sciences are concerned their links to technical application are too often hypothetical. When molecular biology will become useful to pharmaceuticals, or whether high energy physics will find any application at all, is a matter of speculation, in spite of all the methods of technological forecasting which try to put this speculation on some solid ground.

This uncertainty may place industry and governments in the coming years before difficult choices, especially in small countries which owe much of their standard of living to their skills and which cannot afford to invest equally in all research fields.

Chapter 1

RESEARCH IN INDUSTRY

1. Research, exports, multinationality: the development of a particular industrial system

In some countries— it is industry that performs and pays for the major part of all R & D carried out. Table 1 compares the proportion of R & D financed by and performed within the business enterprise sector in eleven OECD countries. The third column indicates the proportion of industrial R & D which is financed by the government. In four of the five countries— Belgium, the Netherlands, Sweden and Switzerland industry finances itself the bulk of the nation's R & D. Of the big countries, this is comparable only to Germany and Japan. It is true that in France, the United Kingdom and the United States, industry also performs the majority of all R & D but contrary to Germany, Japan and the four smaller countries, thanks only to massive public R & D spending, mostly for defence purposes. Public financing of industrial R & D is also found in other countries, especially in Germany, Sweden, Norway and Canada, but is not of the same relative magnitude as in France, the United Kingdom and the United States and changes the general picture less fundamentally.

Table 1. **Business Enterprise R & D as Percentage of Total National R & D Expenditure (1967)**

Country	Business Enterprise		Proportion financed by Government
	as Sector of Financement	as Sector of Performance	
Belgium	61.2	66.8	7
Canada	31.0	37.7	14
France	31.5	54.2	39
Germany	57.5	68.2	17
Japan	62.8	62.5	1
Netherlands	57.3	58.1	1
Norway	37.5	45.5	18
Sweden	55.1	69.9	22
Switzerland	78.1	76.5	3
United Kingdom	43.0	66.3	32
United States	32.8	69.2	53

Source: International Survey of the Resources devoted to R & D in 1967 by OECD Member Countries, *Statistical Tables and Notes*, OECD, Paris, 1970.

Hence, the dominant position of industry in the research system of four smaller countries is a particular development which calls for an explanation.

According to a widespread belief, this predominance of industrial research is linked to the international trade dependence of the countries concerned and to their high standard of living due to successful specialisation in international trade. However, this demands some qualification.

It is true that the five countries export 20-40 per cent of their GNP, which exceeds the export proportions of any bigger OECD country. But with the exception of Switzerland, a considerable part of these exports still consists of agricultural, fish and forestry products, metals and other mineral resources. (The proportion of total exports are 40.1 per cent for Belgium-Luxembourg, 56.9 per cent for Norway, 45.2 per cent for the Netherlands, 44.1 per cent for Sweden and 10.5 per cent for Switzerland.)[1]

Agriculture and mining industries usually do not spend much on research, at least not as much as the manufacturing industries. Norway has achieved a high standard of living without much industrial research. This indicates that the link between the two has been historical rather than causal, at least at a global level. If one investigates industrial research in the five countries in more detail, it appears that its composition is quite different.

The dominating fact of industrial research in the Netherlands, Sweden and Switzerland is its concentration into a few hands. Table 2 shows for all five countries, the five biggest industrial companies, measured by international sales, and their contribution to the national R & D effort. In the three countries mentioned, not more than five industrial companies spend between half and two-thirds of the national R & D budgets. This is exceptional: in no other OECD country do the five first companies carry out half or almost half the nation's R & D. In Belgium no fewer than 10 companies are required to reach approximately two-thirds of all industrial R & D; in Norway, more than 150 companies.

The size of the big companies, measured by sales, varies among the five countries. The turnovers of the first five Belgian, Swedish and Swiss companies are comparable with each other, but that of the Dutch, or better the British - Dutch companies is bigger by almost an order of magnitude, and that of the Norwegian companies is smaller by almost an order of magnitude (cf. Table 2).

The companies in Belgium, Netherlands, Sweden and Switzerland have one feature in common: almost all of them sell the bulk of their total production, between 80 per cent and 99 per cent, outside their "home" country. This does not apply to Norway's three biggest companies, Borregaard, Akers and Norsk Hydro, which still depend upon the Norwegian market for 40-60 per cent of their sales. Thus, company size in small countries seems to depend upon performance in international trade; in other words, the Belgian, Dutch, Swedish and Swiss companies grew to their present size thanks only to their exports or their multinational structure. In Norway, the smaller size of the biggest companies, the comparatively small industrial research effort and its scattering between many companies

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[1] *Source:* National Account of OECD countries: Foreign Trade Statistics Bulletins: Series A, Overall Trade by Countries, Series B, Trade by Commodities, Analytical Abstracts, Series C, Trade by Commodities, Market Summaries, OECD, Paris.

Table 2. **The Five Biggest Companies (by International Turnover) and their Contribution to Industrial and Total R & D in Five Countries, Approx. 1970**

	Main Sectors of Activity	International Turnover (approx.) in 1970/71 *In Billion $*	R & D Expenditures (approx.) of the five companies *In Million $*	Industrial R & D 1969 *In Million $*	R & D of the five biggest companies *As % of industrial R & D*	R & D of the five biggest companies *As % of total R & D*
BELGIUM						
1. Petrofina	Petroleum Products	1.3	Approximately 40	147	25-30 %	15 %
2. Solvay	Chemicals	0.8				
3. Cockerill	Iron, Steel, Metal Products	0.8				
4. Hoboken	Non-ferrous Metals	0.6				
5. Agfa-Gevaert[1]	Photographic Equipment	0.5				
NETHERLANDS						
1. Royal Dutch-Shell[1]	Chemicals Petroleum Products	10.8	Approximately 230	364	60-65 %	40 %
2. Unilever[1]	Food, Chemicals	6.9				
3. Philips	Electronics, Electric Equipment	4.2				
4. Akzo	Chemicals, Fibres	2.0				
5. Dutch State Mines	Chemicals, Mining	0.5				
NORWAY						
1. Borregaard	Pulp, Paper, Chemicals	0.17	7.5	47	16 %	7 %
2. Akergruppen	Ships	0.17				
3. Norsk Hydro	Petroleum Products, Fertilisers	0.16				
4. Ardal-Sunndal	Aluminium	0.14				
5. Elkem[2]	Metals	0.09				
SWEDEN						
1. Volvo	Automobiles	1.0	Approximately 110	242	45-50 %	30-35 %
2. SKF	Bearings, Metal Products	0.9				
3. Asea	Electrical Equipment	0.7				
4. SAAB-Scania	Aircraft, Automobiles	0.7				
5. L.M. Ericsson	Electronics	0.6				
SWITZERLAND						
1. Nestlé	Food Products	2.8	Approximately 240	331	70-75 %	50 %
2. Ciba-Geigy	Chemicals, Pharmaceuticals	1.6				
3. Brown-Boveri	Machinery, Electrical Equipment	1.3				
4. Hoffmann-La Roche	Pharmaceuticals	1.1				
5. Sandoz	Chemicals, Pharmaceuticals	0.6				

1. Agfa-Gevaert, Royal Dutch-Shell and Unilever are Belgium-German and Dutch-British companies respectively.
2. Since 1972, Elkem-Spikerverket.

can partly be explained by geographical conditions and regional development considerations.

Is it company size alone which explains the large amount and concentration of research in a few firms? The Belgian example suggests that this is too simple an explanation. The five biggest Belgian companies, although not much smaller than their Swiss or Swedish counterparts, spend together much less on R & D than the latter. Some of them grew big on the basis of more traditional technologies and started to innovate and to expand their R & D facilities only relatively recently.

Finally, it appears that the economic sectors which the big companies chose were not simply "science-based" by definition— they became so by need or by will. Volvo performs proportionally more R & D than Renault or Volkswagenwerke and turns out a more expensive "science-based" car. Royal-Dutch-Shell is said by specialists to spend more on R & D than many American oil companies.

Industrial companies in smaller countries grew big as a result of their export or multinational basis. It is true that in the Netherlands and Belgium some of them for some time had the advantage of easier access to colonial raw materials, but in the long run one can say that the surest way to grow was the way through quality and innovation. In other words, companies had to manufacture new, cheaper or better products, they had to find a market "niche" and to reach a dominating position in certain products in as many countries as possible. The need for technological innovation and quality improvements drew science into big companies. This applies to the companies which grew out from a research laboratory, such as Philips or Hoffmann-La-Roche, as well as to those which were first based on more traditional technologies and only later went into independent research such as Volvo or Solvay.

Sweden is the only smaller country which does not owe the large amount and concentration of its industrial research exclusively to international trade factors, but also to its defence policy. This created a situation which is somewhat comparable to that of the United States, apparently without the problems which have emerged there, partly because defence R & D expenditures of the two countries differ by approximately two orders of magnitude.

The Swedish defence policy demands that the major weapon systems are being developed inside the country, and more by industry than by separated government laboratories. Several of the big Swedish companies, especially SAAB-Scania, Volvo and L.M. Ericsson, are major defence-contractors. Hence, a certain proportion of the R & D expenditures of the five biggest companies are government financed and serve defence purposes; since, for the whole of Swedish industry, government support amounts to 22 per cent of all R & D expenditures, one can assume that the corresponding figure for the five companies concerned certainly exceeds 30 per cent.

A final question refers to the multinational structure of many firms on Table 2, especially the Swiss and Dutch companies. Why did the biggest companies not grow on exports alone, but moved an increasing proportion of their activities abroad or acquired an increasing number of foreign subsidiaries? Tariff protection and other obstacles to free trade, as well as shortages of manpower and raw materials in the "home" country played a part in each case. Some, especially petroleum and food companies, were born multinational, they found their structure prescribed by the wide geographical distribution of their raw materials.

For science-based chemical and pharmaceutical companies, patent-protection for new discoveries was vital; in the absence of an international patent-legislation, some of them wanted to have national companies in each important country in order to ask everywhere for patent-protection. This partly explains why Hoffmann-La-Roche was multinational almost from the day of its creation.

In Switzerland and in the Netherlands, financial and fiscal factors, and the availability of managerial resources, helped to promote multinational company strategies. The availability of managerial resources deserves a special mention. The Swiss and the Dutch were willing not only to travel, but to emigrate to and live in foreign countries. This mobility of many people, which has a long tradition in both countries, was a vital and probably irreplaceable asset during the early expansion period of many multinational companies of Swiss and Dutch origin. In Belgium and Sweden, similar traditions were apparently less strong.

The preponderance of industrial research in several of the five countries, and the preponderance of a few big companies within industrial research, was neither planned nor foreseen, at least not by the governments of those countries.

It was rather the result of entrepreneurial initiative and far-reaching decisions of a relatively small number of industrialists in a liberal economic system, to which one may want to add a touch of good luck here and there; in fact, several of the biggest companies on Table 2 have been at least once in their history— usually in their early period— near to bankruptcy, and were saved at the last moment.

Although some of the companies concerned have maintained scientific or technical teams almost since their creation, the relative predominance of their R & D in the national research system is not older than approximately 30 years. No government policy brought this about, but a mixture of need, entrepreneurial will and coincidence. This means that the present situation may not necessarily last forever.

2. Some notes on fundamental research and the organisation of R & D

Looking for fundamental research in the industrial laboratories of the five countries raises the same, if not worse, problems of definition as have been encountered in France, Germany and the United Kingdom. Until recently, the statistics of several OECD countries on "basic research" expenditures by industry varied so much that they cast doubts, on the comparability of the research definitions used. Of the companies visited only one admitted to know and to apply the proposed standard practice of the "Frascati Manual" which defines basic research as "not primarily directed towards any specific aim or application".[2]

However, in spite of statistical problems, it is not difficult to discover that basic research defined in this way is not only a very small, but a decreasing part of industrial research. If it still exists, it does so only in the biggest corporations. The five first companies mentioned in Table 2 cover, with the possible exception of Norway, 90-100 per cent of all industrial "basic" research of their countries as defined in the "Frascati" manual.

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[2] Cf. *The Measurement of Scientific and Technical Activities, "Frascati Manual"*, OECD, Paris, 1970.

Basic research teams which were not closely linked to any company objective did in fact exist in the 1950s and the 1960s in several big companies. Some companies reported that such research led occasionally to unexpected applications and successful products. For example when Hoboken in Belgium started research on titanium, it was considered simply as a scientific exercise and not as likely to lead to successful commercialisation.

On the whole the consideration of such indirected basic research in industry seems to have changed in the past few years: from a source of hope it has become a luxury which industry is less and less willing to afford.

However, this does not mean that "fundamental" research in a more complex, but industrially more relevant sense, is decreasing also. On the contrary, some company statements give the impression that research which advances the frontiers of science is increasingly important to them.

To measure this research which may be called "fundamental" although it is supposed to be ultimately useful, is even more difficult than to measure indirected basic research. Industrial research directors are remarkably reluctant to speak of fundamental or pure research and to separate it from applied research. A chemical research director in Switzerland likes to compare pure and applied research to pure and applied love... Sarcasm which reflects an attitude shared by many of his colleagues. It is related to that refusal to draw an absolute borderline between theory and practice, mind and money, science and application, which has been mentioned as one of the strongest assets in the research system of small countries. Probably, recent financial problems in some of the visited companies, and the consequent pressures on R & D budgets, have reinforced the aversion of research managers against a separation of fundamental and applied research, which might jeopardize the former.

The only manifest exception to this in the countries concerned— at least on a big scale— was found in the Philips company. It has pointed out that 10-20 per cent of its central research in Eindhoven was unrelated and fundamental, undertaken to increase scientific knowledge. This pride in fundamental research has historical origins. The "Physics Laboratory" in Eindhoven was partly the idea of the Philips brothers themselves and dates back to the early period of the company. The Philips Laboratory's past successes in industrial innovation have certainly helped it to retain its relative scientific and administrative independence.

This leads us to R & D organisation in big companies. Some organisational principles and problems are no different from those found in the industry of bigger countries. For example, most big companies in the five countries concerned maintain central research laboratories, in addition to the more product-oriented laboratories attached to many company divisions or products units. Central research is sometimes long-term or "fundamental" research in the complex, industrial sense indicated above.

But even companies with central laboratories of long standing scientific reputation demand that research be integrated into their market and profit strategy. In Philips, it is believed to be essential that even the central researchers in Eindhoven know the market and do not rely exclusively on the feed-back from the applied research, development, production and marketing people to find out which products could be sold. In Hoffmann-La-Roche, one used to refer to the former research director as to a "true director of marketing". These examples testify to the absence of an absolute borderline between science and application which was so profitable to both companies.

The total amount and distribution of the research budget of a big company are the results of a complex game for which there are no universal rules. This game is not unlike the one which is played within a country for the distribution of the national R & D budget. No single person decides on the R & D budget, at least not in big or multinational companies. The research policy of competitors and colleagues is being closely watched and serves sometimes as a guideline. Most R & D expenditures are normally earmarked for longer-term programmes and are therefore not liable to big annual changes. For the remainder, decisions depend upon the company's internal power balance and occasional power struggles.

Beyond this, generalisations are difficult as there is no concensus among industrialists on the "best" research structure or policy. Many companies have a historical bias for or against science. Companies which grew from a research laboratory such as Philips belong usually to the first category. Unfortunately formal measures and labels such as organisational charts or the presence or absence of scientists in the management board do not always reveal the real place and strength of science in a company.

In addition to these general features, multinational companies from the five countries are faced with questions which are unique to them. They result from the multinationality of their R & D, which creates exceptional co-ordination problems in what is probably their most delicate and vital field of activity except for finance.

Whereas Belgian, Norwegian and Swedish companies perform most, if not all, their research within their respective countries —though this may change for some of them— the big Swiss corporations have together probably not much more than half of their R & D personnel in Switzerland, some of the big Dutch corporations less than half. Royal-Dutch-Shell maintains centres in the Netherlands, the United Kingdom and the United States of approximately 2,000-3,000 R & D employees in each country. Philips has 2,400 R & D people in Eindhoven and more than 1,500 people in R & D centres in Belgium, France, Germany the United Kingdom. All three chemical companies of Switzerland have centres in the United States, in Austria etc., and Brown-Boveri maintains close relations with the research centres of its subsidiaries in Germany and elsewhere.

Maintaining communication between all laboratories, avoiding duplication, harmonizing their work with general company objectives are tasks which make major demands on research management and which keep a certain number of people continuously on the move.

There are many problems inherent in a multinational research structure which demand attention. Most interesting for a study on the system of research are the interactions between multinational research structure, individual company strategies and national science policies. Here, new problems and tensions could emerge.

3. Problems and tensions

Except for finance, nothing is believed to be as vital for the future of science-based multinationals as their R & D, which is supposed to yield many of the innovations of the future. Hence, the central management in multinational companies tends to keep research, or at least, central research, as near to it as possible, whereas the transfer of production to the countries which provide the main markets does not seem to create any problems. Even in Swiss and Dutch companies, more of total R & D has remained in the home country than of any other activity, except central management.

It is important to understand the exceptional position of science-based multinational companies which grew out from smaller countries, especially as most of the literature and discussion on multinationals concentrate on companies of American origin. Among the differences which separate American from Swiss or Dutch multinationals, at least two are directly relevant to company R & D. Many of the biggest science-based corporations of the United States have received substantial R & D contracts from their government, and can reasonably expect to receive such support in the future also, though this may not always be of the same size or for the same goals. Public money, spent inside the United States, was one of the main reasons for the technological lead of certain multinationals. No multinational in any of the smaller European countries has received comparable public R & D support, and none has reason to hope that it will ever receive any from its respective home-government, with the exception of SAAB and a few other defence-oriented companies in Sweden.

Secondly, a recent study on American multinationals indicates that only a few of them manufacture or sell the majority of their products outside the United States. For example, in 1964, of 140 firms called "multinational", 87 sold less than 50 per cent of their production outside the United States, 6 more than 50 per cent, and for 47 there were no data.[3] The situation is very different in smaller countries. Most of the big Swiss, Dutch, Belgian or Swedish corporations sell less than 20 per cent, some even less than 10 per cent of their products in their respective home countries, and most keep the bulk of their production abroad. In their case, even a moderate concentration of R & D in the home country is an interesting fact. In other words, the fact that an American multinational sells say 60 per cent of its turnover in America, and keeps say 90 per cent of its R & D at home, is much less extraordinary than if a Dutch or Swiss multinational sells 7 per cent of its turnover at home and keeps 40-50 per cent of its R & D at home.

These two differences between American and small country multinationals seem to imply that the R & D organisation of the latter is, in principle at least, more exposed to the winds of change caused by foreign factors.

It is not difficult to understand why the multinationals of smaller countries cannot perform all research at home. The scattering of research into different countries has primarily scientific and historical reasons: it allows a company to keep in direct touch with the progress of science in all relevant countries and sometimes it was an inevitable consequence of mergers and take-overs: normally mother companies do not immediately remove the centres of new subsidiaries.

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[3] Raymond Vernon, *Sovereignty at Bay, the Multinational Spread of United States Enterprises*, New York, London, 1971, p. 122.

In addition, the small size of the home countries— which are often unable to provide sufficient specialists of the right qualifications —forces the multinationals to perform research abroad. Recently, Sandoz of Basle has set up a research centre in Austria of 300 people, almost at third of its R & D staff in Switzerland, where it has become very difficult to find suitable personnel at an acceptable price. In 1969, SKF decided to create a multinational research centre in Holland with more than 100 people. This is quite new in Swedish industrial history. It is due to the high cost of research in Sweden and possibly to difficulties of finding certain specialists. The decisive factor was probably a wish of SKF, Sweden's most multinational company, to have an R & D foothold inside the European Common Market, which Sweden as a country has decided not to join.

The experience of some firms has shown that such trends may one day tip the research balance in favour of another than the original home country and provoke considerable tensions inside companies. For, once a company is multinational, there is no guarantee that its board of directors and management will forever remain in the country of origin, or that it will always be composed mainly by nationals of that country, as is still largely the case in Belgium, Switzerland and Sweden. If it is true that R & D is vital and therefore closely linked to central management, geographical changes in the points of gravity of R & D may also ultimately jeopardize the national composition and localisation of the main management boards of the multinationals.

In one big corporation, the research of one national branch increased partly thanks to government support in that particular country. Apparently, this research left that of the mother-company behind in scope or quality, provoking internal discussions on the "real" centre of the company. As a consequence, central management, with some publicity, hurriedly created a fundamental research centre in its immediate geographical proximity.

In another big corporation, a discovery which occurred in the research laboratory of a main foreign subsidiary led to a large increase in the global turnover and income but apparently also to internal tensions, since the original national "label" of the company in the eyes of the public did not change, and its top management and financial control remained entirely in the home country.

On the whole, changes in the research and innovation balance between national branches of multinational companies develop slowly and can sometimes be foreseen, although surprises cannot be excluded.

Another problem which seems to be a source of growing worry to some multinationals is the interference of political factors which make rational R & D planning —rational in terms of company interests— much more difficult than it need be from a strictly economic point of view. In fact, some multinationals carry out research in countries which they would prefer not to mention, while they have to mention research done in other countries which they would prefer not to carry out. In the first case, companies do not like to talk about R & D laboratories in certain countries, lest the tax authorities there get too interested in the particular contribution which research and innovations in those laboratories may have made to the revenues of the corporation. On the other hand, governments understand more and more the importance of R & D to the industrial and military strength of nations. This explains why some governments try to coerce multinationals into establishing not only production units, but also R & D laboratories in their country, for reasons of prestige and because they hope to profit from them in building up a national R & D potential. Some countries do not permit the multinationals to repatriate their profits, and the directors sometimes conclude that the relatively least wasteful utilisation of untransferable funds was to spend them on research.[4]

While some governments demand that multinationals carry out more research, others are concerned that they do too much. Senior Dutch officials have raised the question as to whether the concentration of multinational company research in the Netherlands does not represent an overproportional contribution on the part of their country to the economy of other nations, since the bulk of the production and sales of the multinationals takes place outside the Netherlands.

It is interesting to see the similarity between this argument and that of the Science Council of Canada, although the two cases are different.[5] The Canadian authorities point out that a considerable proportion of R & D in their country is performed by companies which have their headquarters abroad. Often, their Canadian R & D does not aim at solving Canadian needs and problems, but general company needs unrelated to Canada. Since there is some similarity between this situation and that of Belgium, similar questions may also be asked some day in that country.

The arguments behind the Dutch and Canadian attitudes are not unrelated. As governments discuss new national needs of science policy, difficulties concerning the aim and location of multinational company research may emerge, especially in countries where a big proportion of all R & D is performed by multinational laboratories. Here, the research policy of multinationals may have a considerable impact on the national science system, whereas national governments may not always have a parallel influence on the research strategies of the multinationals. Although the Netherlands provide an example of good co-operation between government and multinationals, it will not always be an easy task to make multinational research strategies compatible with national science policy.

The following section on the contribution of industry to science leaves no doubt that, on balance, research in the five countries and especially in the Netherlands and Switzerland has benefited remarkably from the big corporations. Nevertheless, it would be unwise to ignore the fact that big companies have also made mistakes in their science and technology policies which have sometimes had wider implications for their countries. According to some observers, the unsuccessful effort of the Philips Corporation in the computer sector has had some negative effects on computer science and technology in the Netherlands, and the fight between the two leading Swiss engineering companies for a dominant position in nuclear reactors is said to have left some traces on nuclear research and engineering in Switzerland, although both companies have since to some extent lost their interest in this field after realising that they could not compete in the international market.

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[4] As an example of the problems which multinationals encounter in countries which have become aware of the importance of R & D, one may cite a company which has been forced to create an R & D laboratory in an underdeveloped country, but discovered soon that the "native" scientists whom it had hired belonged to a despised minority which alas was the only part of that country's population to show interest in science.

[5] Cf. Arthur J. Cordell, "The Multinational Firm, Foreign Direct Investment and Canadian Science Policy", *Background Study for the Science Council of Canada*, Ottawa, 1971.

Finally, there is another problem which must be mentioned here: a certain levelling-off of industrial R & D. This is typical not only of these five countries, but also of several other OECD countries. A research crisis, first apparent in the United States, seems to have affected some of the big companies in the five countries concerned, with the possible exception of Norway. In certain companies, some programmes have been brought to an end, and R & D expenditures have ceased to increase at the same rate as in the 1960s. Some companies are relatively open about it, others not. A big company which saw its turnover go down by 1 per cent in one year and reduced its R & D by approximately 25 per cent the following year may represent an extreme case.

If economies are necessary, the R & D budget lends itself often easier to cutbacks than other budgets, because the possible negative consequences of such a policy will not make themselves felt immediately. Difficulties quickly reveal that the directors of finance are usually stronger than the directors of research, even in "science-based" companies.

However, it would be wrong to restrict the present changes to economic difficulties alone. A certain reconsideration of the purpose and organisation of R & D is apparently taking place in industry; for example, companies have put an end to the work of some of the teams performing free basic research. The changes are not limited to these groups, which have never been very big. During the 1950s and 1960s, a general research euphoria led many companies to hire considerable numbers of R & D personnel. In some cases, quality may have been neglected in favour of quantity. Today, some companies are asking themselves how useful R & D has really been, how many successful innovations have come out of their laboratories and whether the same results would not have been achieved with fewer R & D employees, mainly by selecting and utilising them better.

In other words, principles of economic rationality which may have been temporarily forgotten are now being applied to the appreciation of industrial research. Although the focus in industry is shifting from "research" to "new products", few big companies believe that science will be less important in the future, but many seem to believe that scientists could be used more efficiently than they were sometimes in the past.

The question is, of course, whether some are not already exaggerating by going to the other extreme and putting too much pressure on research today because they financed it too lavishly before. The answer to this question is not easy, as it depends on an assessment of the relationship between R & D, technological innovation and commercial success. In the past, the relatively lavish support for R & D in some companies was at least partly the result of a conviction that there was a simple and direct link between industrial research and commercially successful innovation. Today, this conviction has sometimes given way to doubts and a more complex analysis. Manifestly, some of the industrial research in the past did not yield innovations, while some industrial innovations were contributed by other than the R & D departments. Nestlé, which has a strong positive bias towards research, estimates that approximately half of its successful innovations are conceived in the R & D laboratories, whereas marketing, production and other departments contribute the main ideas for the other half. While this confirms that research is vital to the innovative capability of a multinational firm and, relative to cost, is much more innovation-productive than any other company activity, it also shows that the contribution of other activities to innovation cannot be ignored.

It is possible that the importance of marketing for generating new innovations may increase relatively more than that of research,[6] though it will not be easy to separate clearly between the two. Careful investigation into need and demand may become relatively more important for industrial innovation, compared to the importance of original scientific ideas. If this is the case, the cutting down of some industrial R & D may have no negative consequences, but if not, present cut-backs are likely to harm the long-term future of some companies.

4. The contribution of industry to science

Paradoxically, it is sometimes easier to assess a multinational company's scientific than its economic, contribution to a small country. In the countries concerned, this contribution takes many forms, but three seem to be more important than the others:

a) The production of new scientific knowledge;
b) Knowledge transfers from industry to the university through personnel mobility;
c) Technology transfers within industry through personnel mobility.

A. *The production of new scientific knowledge in industrial laboratories*

By sheer size, the laboratories of the big companies rival with the biggest faculties of their countries, if they do not leave them behind. By comparison with them, government research centres are in most cases very small contrary to the situation in big countries. No single Dutch or Swiss university can compete with the thousands of R & D employees who work in the Philips, Shell, Ciba-Geigy etc., centres. The Solvay, Agfa-Gevaert, SAAB-Scania centres are the size of the main science and technology faculties of Belgium and Sweden. As a result of R & D efforts on such a scale, most big companies have achieved world recognition in various fields of science or technology: Unilever in fatty acids and their relationship to cardiovascular diseases, Philips in magnetics, etc. This means, of course, that within the relatively small precincts of their own country, some companies dominate entirely in certain fields of science or technology.

In 1970, the "Journal of Physics and Chemistry of Solids" published 5,451 articles, of which 132 or 2.4 per cent came from the Netherlands, and 72 or 1.3 per cent of these from industrial laboratories in the Netherlands. In 1970, its supplement "Solid-State Communications" published 3,033 articles, 64 or 2.1 per cent came from the Netherlands, of which 50 or 1.65 per cent came from Philips alone.[7] One must add that Philips has a very open publication policy. Some other companies share this policy only with moderation, whereas others such as Agfa-Gevaert consider a publication as a sign that a research project has failed.

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[6] Cf. Among others, "Success and Failure in Industrial Innovation", ***Report on Project Sappho*** by the Science Policy Research Unit, University of Sussex, London, 1972.

There is little doubt that, in some fields, the university has lost its leadership to industry and has difficulty in keeping up with the latter's pace in advancing the frontiers of knowledge. It is not simply the relative or absolute quantity of industrial research which has put it in its present position. As already noted, many companies do not want to use the term "fundamental" research. Many of them, however, are groping for a more adequate term for that part of their R & D which seems to be different, although linked to company objectives and therefore is in principle "applied": "background research" (Royal-Dutch-Shell, Agfa-Gevaert), "learning research" (Nestlé), "pioneering research" (Dutch State Mines), "exploratory research" (Ciba-Geigy), "pilot research", etc. As a matter of fact, some of the R & D of these companies is in quality, depth and novelty comparable to the best university research, and occasionally even better. It is no accident that the research atmosphere of big industrial laboratories in the countries concerned seems sometimes so similar to a university atmosphere, at least as far as a visitor can deduce from external signs. Often, industrial research directors are more reminiscent of university professors than of industrial tycoons, something which cannot be said of all their colleagues in France, Germany or the United Kingdom.

Another similarity between academic and industrial research principles is the emphasis which industrial directors lay on quality, and their experience that the productivity of one first-class man can be out of all proportion to his numerical weight in the R & D staff. There are indeed some famous case stories of breakthroughs leading to big commercial success which were due simply to one brilliant man (DDT in Geigy, or Librium in Hoffman-La-Roche). But there are additional factors which explain the productivity of some industrial research in small countries.

Not only is some industrial research able to compete with academic research, but it does not suffer from some of the latter's institutional shortcomings. This may well be its most decisive advantage, since the particular ways of organising research in big corporations might finally be more appropriate to the advancement of science— even of pure science— by the end of the 20th century than the traditional structure of many universities.

Big industrial laboratories lay emphasis on the multinationality, multidisciplinarity and in some cases the long term perspective of their research. Most big corporations have instituted a regular rotation of their R & D people in different national laboratories, thus creating a cross-fertilisation of different national experiences. Although international co-operation also exists among university scientists, multidisciplinarity as a daily reality and in a larger scale exists only in industry and some government laboratories.

Almost nowhere have universities been capable of abolishing the walls between faculties, disciplines or institutes, in spite of various efforts.[8] Moreover, industry, sometimes gives researchers a chance to quit their original field of specialisation and to retrain in a new one; for an academic researcher, it is almost impossible to move from one faculty or discipline to another.

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[7] G. W Rathenan, *Natuurkunde in de Nederlandse industrie*, N.V. Philips, M.S. 6941, mimeographed.

[8] Cf. Part. II.

The multidisciplinarity of big research teams in industry is probably one of the reasons for their quicker progress in new science-based technologies as compared to universities.

As the financing of public and university research gets more difficult, the long term perspective of some industrially financed programmes— where they have not been cut— becomes an increasingly vital asset for the success of advanced research. The readiness to finance a research programme during a long period provides researchers with a feeling of security and a time perspective which can be very important. The cut-backs of industrial R & D budgets which have been mentioned already have reduced this relative advantage on the part of industry. It is very difficult to see whether there is a permanent change of trends in this respect; probably there are considerable differences between companies.

B. *Knowledge transfers from industry to the University through personnel mobility*

The transfer of knowledge from industry to the university takes place resulting from the appointment of active industrial researchers as part-time university professors, and through the mobility of researchers who leave industry permanently to join the university. Both methods help to fill teaching and research gaps in universities. University teaching by industrial scientists is known in Germany, where it helps industry to discover and attract good graduates. There are several cases in Belgium, Switzerland and Sweden. But it is in Holland that this original idea was developed into the main method of achieving an industry-university interface. Approximately 170, or a quarter of the Dutch university professors in science and technology, are active industrial researchers. Dozens of senior researchers from each of the big industrial laboratories and many from smaller companies are teaching. Usually they take off one day per week, or 15 per cent of their working time, in full agreement with their companies who know that it is in their own ultimate interest to contribute to the universities of their country. The Dutch universities offering such facilities to "outsiders" show an institutional flexibility which is rare elsewhere in higher education. This is the modern expression of a century-old tradition originally intended to permit all religious denominations to teach freely the principles of their faith. When the challenge to survival no longer came from religious wars, but from economic competition, this tradition took a new direction, the reinforcement of the industry-science interface.

The mobility of industrial researchers towards the university for permanent, full-time appointments is another form of knowledge-transfer which the Netherlands appear to have developed more than other countries, although it is known elsewhere, especially in Switzerland. Approximately half of all the physics and chemistry professors in Dutch universities have a long period of active industrial research behind them: of 92 physics professors, 25 came from industry, mostly Philips. The Shell laboratory in Amsterdam provides annually two or three professors to Dutch universities; approximately 60 of the active Dutch professors (all disciplines) came from Shell.

Until recently, this was pretty much a one-way street: there was almost no mobility from the university towards industry. Mobility was probably an outlet for some researchers who were not too happy in industry. During recent years, university and student problems have caused some university professors to become more interested in joining industry.

C. *Technology transfers within industry through personnel mobility*

In small countries, it is the big corporations which are the pacemakers for science and technology in industry. Certainly, in Sweden and Switzerland, and possibly in the Netherlands, many industrial researchers spend the first years of their professional career in one of the biggest companies and move later to a smaller company, usually into a higher position. There is also some mobility from small to big companies, but much less. Thus there is a steady technology transfer from big to small companies and the standard of the big corporations influences the quality of industry out of proportion with the big companies' own economic production. In Switzerland, there are few research engineers who do not spend the early years of their professional life in Brown-Boveri, or in Sulzer. Later, many of them do research or become responsible for R & D or for general management in smaller companies.

In Sweden, SAAB-Scania and possibly a few other companies perform a similar function. More than 10 leading R & D managers in Swedish industry have come from SAAB. This is no accident, for SAAB has organised the biggest research programmes ever carried out in Sweden, especially for the construction of the Viggen fighter which cost approximately $400 million in R & D alone. Thus, Saab has provided many engineers with an invaluable management experience.

Of course, there are many other industrial contributions to the university sector: the creation of new Chairs— Volvo recently helped to establish a Road Safety Chair at Chalmers University of Technology, or the introduction of new sciences— Glaverbel, the Belgian glass company, has introduced vitreous state sciences to Belgian universities; or fellowships for Ph.D. students— the Swiss chemical industry financed 30 of the 35 Doctor theses being written in 1971 in the chemical faculty of ETH Zürich. In Norway, industry (e.g. Norsk Hydro) provides scholarships for postgraduate studies in Trondheim.

The chemical companies in Switzerland are outstanding examples of an industry which does not hesitate to undertake operative and permanent action to complement that of the university— or of the government— if it seems to be lacking in initiative. For example, certain university professors, whose teaching and research are considered to be of vital importance to Switzerland, receive additional financial contributions from industry, formulated as a consultancy contract, which should ensure that they will not leave for better paying universities abroad. A very original form of action is the creation of fundamental research centres in Switzerland. These are completely financed by industry yet act as independent institutes without industrial interference and remain in open scientific communication with any other research centre in their fields; e.g. the Immunology Centre of Hoffman-La-Roche and the F. Miescher Centre for Biochemistry of Ciba Geigy. Although both are directed by academic researchers, there is no intention of integrating them into a university, contrary to similar examples of industrially initiated research centres.

Inevitably, the influence of industry often goes beyond direct contribution and may also indirectly affect science and university policies. It was no coincidence that the second technical university in the Netherlands was established in Eindhoven and the fourth in Sweden in Linköping—both centres of big corporations (Philips and SAAB-Scania). The biocentre of the University of Basle was to some degree helped by the Swiss chemical companies.

These different elements when added together, show that in some countries, especially in the Netherlands and Switzerland, big company research plays much the same role as the "peripheral research system" plays in France, Germany or the United Kingdom: it is industry which creates centres of excellence, initiates research in new fields not covered by the universities, provides multinational and multidisciplinary approaches, offers new options to academics who want to leave the university, and provides a training ground for future university professors.

The big companies in smaller countries realise that their scientifically dominating position gives them public responsibilities which their counterparts in the bigger countries do not have. This is why they accept the need to support university science, although they admit they are not always happy about it: Dutch companies, for example, do not necessarily like to lose first-class people to the university.

However, this responsible attitude on the part of industry should not blind one to the possible dangers of a tradition which leaves much of a country's research policy to the automatic working of a liberal industrial system. There are too many factors which might have nation-wide scientific implications: financial difficulties and a changing appreciation of research on the part of industry, feuds between companies, or simply the absence of industrial interest or competence in certain fields of science.

Chapter II

THE CONTRIBUTION OF THE UNIVERSITY SYSTEM

The success of industry and industrial research in small European countries has been conditioned by an exceptionally favourable educational environment.

This environment began to change in recent years. To understand the possible consequences for industry and research, an explanation of the traditional industry-university interface is necessary.

Of the different elements which made up the educational environment, none was as decisive for industrial research as the technical universities. In this respect, there are similarities between four of the five countries concerned: Sweden, Switzerland, Norway and the Netherlands. The dearth of relevant data does not permit a comprehensive measurement of the contributions of technical universities to industrial research and research manpower. However, at least for Sweden, some relevant and detailed statistics are available:

Table 3. Educational Background of R & D Manpower in Swedish Industry, 1967[1]

Swedish Industry employed:				
21,000	people on R & D, of whom			
	14,200	had some further education, of whom		
		12,693	had technical or scientific training, of whom	
			2,797	technical university engineers (doctorates and first degrees)
			5,093	technical college or "3 year" engineers
			4,229	other technical training
			574	scientists and medical doctors, different categories and degrees.

[1] *Source :* PUFF, *R & D News*, Pharmacia Scientific Information Department, (RI), Uppsala, Sweden, No. 401, 30th August 1971.

In other words 574, or less than 4 per cent of the R & D staff with further education in Swedish industry, were general university graduates.

The bulk of industrial R & D is directed and carried out by graduates from two technical universities, supported by a greater number of technical college graduates and technicians. It is true that Sweden is somewhat exceptional because of the small size of its chemical industries. In other countries, the chemical industries often employ university scientists, especially chemists, but even in Switzerland and Holland, where this applies, the technical universities have always been regarded as a primary source of industrial research staff.

In fact, the technical universities of the four countries train not only practical engineers, but industrial researchers too. In this respect they combine some of the functions of the American elite engineering universities, such as MIT, with the functions of some of the more traditional technical universities and colleges in Europe.

This development was not entirely planned, it started, except for Norway, more than a century ago, mainly as a result of economic needs. The first technical universities listed below were responsible for training the majority of the present industrial researchers and for carrying out a large part of all industry-related university research in the four countries concerned:

First Technical Universities

Abbreviation	Title	Town	Year of foundation	" University " since
KTH	The Royal Institute of Technology	Stockholm	1827	1827
" Chalmers "	Chalmers University of Technology	Göteborg	1829	1937
" Delft "	Delft University of Technology	Delft	1842	1905
ETH	The Federal Institute of Technology	Zürich	1854	1854
NTH	Technical University of Norway[1]	Trondheim	1910	1910

[1] Official name since 1972: The University of Trondheim-College of Technology.

New technical universities have been created in the past few years. Before their impact can be understood, the "élite" position and industrial aim of their elder sisters mut be appreciated.

1. Technical universities as "élite" schools

Sweden, Norway, the Netherlands, Switzerland did not plan for "élite" schools in any traditional social or political sense when they founded their first engineering schools. They aimed at providing sufficient engineers for the economy and particularly public works in line with the university policy of the surrounding big powers which they had studied closely.

However, in Scandinavian countries, in the Netherlands and Switzerland, the social prestige of technicians and later of engineers seems to have been higher from the beginning than that of their colleagues in France, the United Kingdom or Belgium. In most small European countries, engineers do not usually rank below scientists, either in social esteem or in income. Many economic and cultural factors help to explain this.

Only two generations ago, the majority of the populations of these countries were independent farmers, fishermen and crafsmen of different protestant denominations. This background may explain the survival of traditions which value practical, economically rewarding work— and ultimately applied research and engineering— as highly as purely intellectual work. The fact that most scientists became school teachers certainly helped to raise in comparison the prestige of engineers, and while this was probably not very different in big countries, it seems that in small countries the profession of science was more readily associated with school teaching, probably because famous old science faculties, institutes and academies which gave pure scientists an independent social function were in small countries often less conspicuous or important.

Finally, in some cases engineers fulfilled roles which the country considered as vital to its survival: in the Netherlands, the dam builders were engineers.

The traditions helped to give considerable prestige to the schools which trained engineers and prevented them from being regarded as a second choice. But it took additional factors to turn technical universities into élite schools.

The fact that each country needed and created only one technical university was probably quite important. The foundation of two in Sweden contradicts this only apparently: Stockholm and Göteborg are widely separated geographically and their technical universities serve two very separate parts of the country. The teaching potential in technology available to a small country was therefore concentrated in one place. Technical universities became from the very beginning national instead of local centres of learning, in contrast to many classical universities. They inevitably attracted professors and students from all over the country and so probably avoided the parochial spirit that dominated so many of their older, tradition-oriented sister institutions.

Moreover, by limiting engineering to one school, smaller countries did not have to duplicate technology Chairs in the same disciplines. This made it easier to select the best candidate for a Chair if there were several applications.

The exclusiveness provided by having only one school had an additional advantage: the prestige of engineering became attached to one name and one title; this was difficult in countries where technology was taught in several schools.

A second reason which helped to turn some engineering schools into "élite" schools was the higher cost of teaching and research, as compared to the pure sciences. This forced technical universities to introduce recently numerous clausus or entrance examinations, usually unknown in general universities, except for the medical schools. This, and an often very difficult curriculum limited the access of higher technical education to the "better brains" among the students, often defined by secondary school performance, and added to the élite appeal of technical universities.

It is possible that the less specialised and more balanced curriculum of grammar schools in small countries, and the appreciation of practical capabilities and applied sciences in secondary and higher education, played a very positive role. The whole school system may have designated those pupils as "best" who were really most suitable for engineering. Too exclusive an emphasis on theoretical knowledge, especially mathematics, such as can be found in some big countries, may often have resulted in something short of the ideal selection of pupils for engineering schools.

Finally, probably all technical universities in small countries profited at some time or another, if not permanently, from special government attention. Most conspicuous is ETH, Zürich. This technical university is federally financed, whereas all general universities are the responsibility of the cantons. Originally, the Swiss Confederation planned to create not only a technical, but a general university of its own, but the latter had to be dropped because of cantonal opposition. This left ETH as the only object of federal interest and support in education. As a result, ETH professors have always received higher salaries than general university professors in Switzerland except, more recently, for professors at the University of Zürich. This of course has helped to attract excellent teachers to ETH and has added to its élite appeal.

The situation of Belgium differed from that of the other four countries. Belgium has one of the oldest manufacturing and industrial traditions in Europe, but lacked some of the general social and educational patterns conducive to the creation of technological élite schools.

Engineers did not always seem to enjoy the same prestige as in the Netherlands, Switzerland and Sweden, and were sometimes not considered equivalent to scientists. To repeat remarks made by responsible researchers in the countries concered: in Switzerland, the engineer is a "synthesizer" of science, in Belgium he is a "vulgarisor" of science. Belgium has in this respect more in common with France than with small countries. Before Belgium became politically independent it had to adopt parts of the French educational system which did not favour the creation of a central technical élite school geared to the needs of industrial research. Whereas Belgian universities provided for the training of civil engineers in "applied science" faculties, technical engineers were trained, until a few years ago, in engineering colleges: in the eyes of many their subject did not really fit into a university. Belgium has no comprehensive technical university comparable to Delft or Stockholm; many Belgian universities have their own applied science or engineering faculties. Possible this has spread the technological teaching and research potential of Belgium too thinly at least in the past.

2. Technical universities at the gates of industry

The Ecole polytechnique in Paris is certainly recognised as being an "élite school" in technology, but it did not train its pupils sufficiently in research, and it prepared them for civil service and military careers rather than the industry of the schools in the higher education sector which train industrial engineers —the "Ecole des Arts et Métiers"— ranked as a second, if not third choice in the educational prestige scale. The Imperial College in London is in effect, if not in constitution, an élite university in science and technology, but it too has never been fully geared to the research requirements of industry.

Contrary to this, the technical universities in Switzerland, the Netherlands, Sweden and Norway train their pupils for industry, not only by means of their curriculum, but by giving them industrially realistic attitudes and motivations. Close and regular associations, took place between the first technical universities and important science-based companies which often developed very early. Gerald Philips graduated in 1883 from Delft in mechanical engineering and founded in 1891 the Philips company. G. Holst inaugurated in 1914 the Physical Research Laboratory of Philips and later became

President of Delft Technical University. The Swiss electrical and machine building industries have long been closely linked to ETH in Zürich. Today, some general managers and most R & D managers of the bigger companies were trained as engineers in the same schools, and have often known one another since their student days. This applies to the "Big Five" companies in the Netherlands and to the Swiss, Swedish and Norwegian engineering companies. This, perhaps, as much as anything else, has maintained the bridge between industry and technical universities.

Looking for concrete signs of the industry-university interface, research in technical universities seems to have played a major role in this context. Although there are no comprehensive statistics on research carried out by or in collaboration with technical universities, technical universities in small countries do, in fact, lay great emphasis on research and have often done so for several decades. All the five universities mentioned above stated that research is necessary for maintaining their quality and relevance.

In other countries, not all engineering universities are carrying out research which involves post-graduate students. However, it is perhaps more the direction than the mere existence of technical university research that counts. Apparently the bulk of all technical university research in small countries is of interest to the national industry. This is to no small degree due to the close association of industrial research institutes and technical universities. The small size of many companies led to the creation of co-operative research institutes for the whole industry or for industrial branches. Often, these institutes were closely associated with a technical university or intregrated with a university institute, thus making the responsible professor director of an industrial branch research institute.

The industrial research laboratories of TNO, the Central Organisation for Applied Scientific Research in the Netherlands, are geographically a part of the Delft Technical University Campus. In Norway, the biggest industrial research institute, SINTEF (the Engineering Foundation at the Technical University) grew out of the Technical University Trondheim, and was originally meant to keep engineering training relevant. Employing in 1972 540 people as a legally independent centre, its policy is to accept research contracts only in fields where there is a scientific background at the university. Eight out of SINTEF's eighteen department heads are university professors in Trondheim. In Sweden, several institutes of Chalmers in Göteborg and of the KTH in Stockholm developed into major R & D centres for industrial branches or activities (textiles, metal working, mineral processing).

All this does not mean that the technical universities of small countries spend all their time solving technical problems for industry— but it does mean that much of their research, even when fundamental, is done in fields which are industrially relevant, and that most engineering students grow up in an environment which is realistically aware of industrial research. It is possible that this finds expression in the curriculum of technical universities. Average engineering courses in small countries, for example in Sweden, are said to include a relatively large amount of training in research. Only a comprehensive enquiry would bring out whether this is generally true.

Several experts have observed that technical universities in small countries often give their students a less specialised but broader training than many technical universities in big countries. This prepares them better for technical change, and facilitates personal mobility of engineers between different companies and fields of activity. Limited resources and small size may have prevented the technical universities from offering the same number of highly specialised curricula as are found in bigger countries. If this is the right explanation, it would be another example of how the research system of small countries has turned the initial disadvantage of small scale ultimately into a certain advantage even if some of the smaller technical universities regretted that they did not have the same possibilities as their bigger counterparts.

Finally, the industrial orientation of technical universities appears clearly in the regulations of many of them which demand from new students a certain time (mostly six months) working in industry before they can enrol.

For teaching appointments, industrial experience on the part of applicants is an advantage, and for quite a few Chairs even a legal requirement. This practice is said to be more widely established in small than in large countries, but more quantitative evidence is required to verify this. It is certainly significant that academic tradition at ETH Zürich provides no obstacle to appointing as academic head an engineering professor who started his professional life as private entrepreneur and not as university teacher or researcher.

On the whole until recently technical universities in small countries often gave the impression of being more flexible and innovative as institutes, and more receptive to new ideas and disciplines than many general universities. It is interesting to notice in this respect that industrialists in small countries appear to be much less prone to complain about the quality of engineers than their colleagues in France, the United Kingdom or even the United States.

This comparative receptivity and flexibility of technical universities was linked to their economic purpose, and confirmation of some dialectic law seems to be implied because technical universities were not geared to the advancement of pure science, but to the solution of practical problems, they developed institutional attitudes and structures which in some cases were ultimately more favourable to the advancement of science than certain structures of older and less flexible general universities.

3. Technical universities at a crossroad: changes and dangers

What has been said in the preceding pages describes the working of a system which may be approaching or have come to an end in some countries. An analysis of this system appeared necessary since its possible implications of important changes are not always fully appreciated.

Several developments seem to herald such changes: a fall in the prestige appeal of engineering professions, the inevitable multiplication of the number of engineering universities, and a possible decrease in the "quality" of certain technical faculties which some observers have noticed, and which may indicate that technological university education has not always adapted itself to a changing economic and social environment.

In recent years, the general atmosphere surrounding technology has changed in highly industrialised countries. Technology, increasingly associated with pollution and war, has lost some of its original appeal. This change of attitude, which first emerged in some bigger nations, is apparently also being felt in small European countries. Professors and industrialists alike report that the general interest in technology and applied science seems to be decreasing, for example in Switzerland and Sweden. Whereas ten years ago the best students opted for engineering, now this is not always true, and a number of them today would prefer biology, medicine or the social sciences. Teachers in one of Switzerland's best known applied science faculties have observed an increasing unwillingness on the part of their students for applied and detailed work, and an increasing desire for theoretical studies. Not all of this is due to the much lamented "crisis of civilisation". The levelling-off of industrial R & D employees— even if it concerned only a few and even if the press exaggerated the problems— has had some resonance and has influenced the minds of young people. Moreover, it should not come as a surprise that the problems of mature and established technologies— such as machine-building in Switzerland or shipbuilding in Sweden— do not attract the same proportion of the best, most daring or most innovative young people as they did one or two generations ago.

There is no consensus among professors or industrialists on this problem, some professors find their engineering students are as excellent and numerous as ever, and many industrialists confirm that new engineers are as good as their elders. Probably the changes which have taken place are too recent to allow for a judgement as to whether they are lasting or widespread. However, if it is true that in small countries the success of industry, technology and sometimes even science was due to the tradition of the best brains choosing engineering, even small changes in this tradition must cause concern.

Another and certainly lasting change to the old system is the multiplication of technical universities. Except for Norway, the time when the prestige of the engineering title was attached to one school of old standing has come to an end. The Netherlands created a second technical university in Eindhoven (1956) and a third one in Twente (1964), Sweden a third one in Lund (1961) and a fourth one in Linköping (1969) while the creation of further schools is under discussion, and Switzerland finally turned the polytechnical school of Lausanne into a second federal technical university (1969). Several factors made this development inevitable: an increasing demand for engineering education which the first technical university alone could not satisfy; local or regional politics; and, finally, the difficulty of having different engineering schools with approximately the same syllabus, without calling them all "university".

In Norway, the eventual creation of a second technical university or the establishment of an engineering faculty at the University of Oslo has often been discussed, but until now, it was thought more efficient to concentrate engineering teaching and research in one school, instead of splitting it.

Some experts hoped that, as a result of competition, new technical universities would raise the general quality of engineering education. The discussion on the advantage or disadvantage of creating several technical universities in countries such as Norway with limited potential is not yet closed. However, on the basis of Belgian experience, it would seem that dissolving technical universities as special units and integrating all technical education into general universities, as it was once suggested for Sweden,[1] is not necessarily the best way to maintain high quality in engineering.

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[1] "Development of Universities of Technology in Sweden", Office of the Chancellor of the Swedish Universities; Council of Europe, Strasbourg, 11 August 1970: CCC/ESR (70) 30, p. 18.

Of the four countries concerned, the Netherlands have the longest experience with the simultaneous development of an "old" and a "new" technical university, since the Technical University of Eindhoven has functioned since 1956. It is interesting to listen to the apprehensions of some Dutch industrialists who fear that the "quality" of Delft Technical University has deteriorated since the creation of Eindhoven.

Although changes in one university do not necessarily influence other universities, this opinion does reflect a diffuse malaise with regard to the "quality" of technical universities which one finds in other countries as well. This should not be ignored, even though expressed neither precisely nor convincingly.

Technology has become a very complex matter during recent years, not only in its industrial and military applications, but in its consequences for science and in its wide implications for society and politics. It is possible that technical universities have not always adapted themselves to the increasing complexity of the technological environment and that some faculties may therefore be less pertinent to the environment than 20 or even 10 years ago. If this explains the complaints about decreasing "quality", technical universities may have to make a greater inventive effort to adapt their teaching and research to a changing economy and society.

For obvious political reasons, it is difficult for governments to discuss problems of technical— or any other— education from an "élite" or even from a "quality" aspect, as has been done here. The old universities in the four countries were élite schools *de facto* and not *de jure*, their possible decline as the unique centres of excellence in technology is not more planned than was its emergence. Their "élite" aspect did not reflect social class structures but industrial needs. However, industry claims that its needs for the best brains of the country are not less but even more urgent than before. From this point of view, some of the changes which seem to be occuring in the relative position and "quality" of technical universities might be ominous.

4. The contribution of general universities and some notes on the Industry-University interface

It is interesting to place the industry-technical university interface into the broader framework of industry-university links. Some problems are in fact pertinent to the whole system of higher education and not only to technical universities. Moreover, the science and medical faculties of the general universities have a potential which could interest industry and which, in mere numbers, is superior to that of technical universities. Industry has not used this potential to the same extent in all the five countries neither have the universities been equally well disposed towards industry in all of them.

Netherlands. All universities are apparently open towards industry, and the personnel feedback from the latter to the former probably extends into each science and engineering faculty in the country. This does not mean that university research is always indebted to industry; in certain fields, astronomy for example, Dutch scientists have made an internationally recognised impact for generations without any noteworthy stimulation from industry.

However, a country like the Netherlands which has developed industry-university links further than the others may sometimes wonder whether there is not a sort of natural ceiling to such links. These links have probably benefited both sides, contrary to the situation which seems to have developed in some American universities in the 1960s. But the defensive reaction of some Dutch university scientists who were asked about industry-university links raises some questions. Professors who harbour no ideological motivation against industry have remarked that the university has sometimes to make an effort to keep open the possibility of doing free research. Few university researchers think that there are insufficient links with industry. Does this mean that there are limits to what the university system of a medium-sized country can do, in quality and quantity, for so big a multinational industry?

Switzerland. As in the Netherlands, general science and medical faculties have been open to industrial initiatives and support, so that their attitude did not differ much from that of ETH, Zürich. In the 1920s the University of Neuchâtel started to train watch-making engineers— then probably a unique profession— after the need for such engineers for the surrounding industry had been recognised. It is the chemical industry in Basle which maintains the closest links with the university system, as has already been indicated. The chemical industry owes some of its success in the past to a few centres of excellence in organic chemistry in Swiss universities, and more specifically to the graduates who were trained there, which explains some of its solicitude for the university system.

However, the traditional openness of universities and ETH to industry has had some negative corollaries, which are slowly coming to light: a university system that depends too much upon industrial direction and initiative risks stagnation in fields where such initiative is not forthcoming. A certain weakness in the Swiss university system in some fields of science and technology is said to be partly due to lack of industrial interest. This, added to a less cosmopolitan policy in many universities during the past 10-20 years, may have slightly reduced the relative international position of Swiss science and technology compared to what it was before. There were recently other signs pointing to disfunctions in the industry-university interface: some industrialists complained that traditional, privileged links between other industry groups and the university system prevented them from getting the collaboration they were looking for. All this seems to indicate that in years to come federal and cantonal governments as well as the university system may want to show more independent initiative in covering important new fields of science and technology.

Belgium. In the absence of a single centre of excellence in technology, the science and technology faculties of Belgium's main universities should have had an important role to play in industry. In fact, in several noteworthy cases (non-ferrous metals, photographic chemistry, vaccines) university professors and their teams initiated and performed major work for some of the country's most successful industrial companies. However, on the whole industry-university relations in Belgium were not so close as they could have been. The traditional structure of Belgian industry and the relatively small number of innovative, science-based companies— to some extent the result of the early industrial development of Belgium— explained a certain lack of interest for science in industry, while most universities in accordance with traditional French models, tended not to get involved with industry. However, it is difficult specifically to blame either industry or university alone for the weakness of their links. This weakness reflects the diversity of Belgian society and a lack of meaningful contact between different social and language groups. Belgium's largest chemical company has had— and possibly still has— no contacts with one of the biggest and most eminent chemistry faculties of the country, because of differences concerning religion and language. In recent years some universities and industries appear to have undertaken new efforts to achieve better relations. The Catholic University of Louvain, for example, endeavours to attract industry to its campus.

However, there was sometimes more industrial response from abroad than from Belgium to such efforts, which seems to indicate that Belgian industry still has a fairly long way to go in this respect. In the future, industry and university will find more partners with whom to collaborate if religious and language obstacles can be overcome; and if they cannot both sides may suffer disadvantages in comparison to their foreign colleagues and competitors.

Sweden. Contrary to a widespread belief outside Sweden, the industry-university interface in Sweden is less strong than in other small industrialised countries, with the probable exception of Belgium. This is not always a sign of weakness. In Sweden, most big companies are independent, strong and experienced in research and even in-house training and in some industries companies in the same sector have developed between themselves an efficient system of research co-operation (e.g. the iron and steel industries through the Iron Masters Association). This, as well as the absence of a big chemical industry, explains to some degree poor industry-university links. Close links do exist between Sweden's technical universities and the engineering and metal-working industries which need engineering graduates, although there were complaints that industrial suggestions on engineering curricula are not sufficiently followed up. However, some science faculties have still not completely overcome that traditional aversion to economic involvement which Sweden shared with some other scientific communities in Europe. One exception to this is the University of Uppsala, whose research played an important part in the development of Sweden's two biggest pharmaceutical companies. Efforts are being made to improve the industry-university interface, as shown, for example in the industrial interest of the Lund Chemical Centre.

Norway. Relations are excellent between Norway's industry and the Technical University at Trondheim with its engineering foundation, SINTEF; sometimes SINTEF cannot find enough personnel to perform all the programmes which industry would like to contract out. This co-operation was possible in spite of the often tremendous geographical distances separating Trondheim from industry. In Belgium, however, even the immediate geographical proximity of industry and university has not been sufficient to create links between them.

Oslo university has not as many links with industry but it is difficult to judge whether this is due to an "ivory tower attitude" on the part of the university, as was suggested in Norway, or to the fragmentation and relatively small size of industry which may not need or may not know how to use more university contacts. The fact that the S.I., the Industrial Research Centre in Oslo, had until recently only poor links with the science faculties, although they are located at the same university campus, would tend to give some credit to the first hypothesis. On the other hand, the recent experience of Norway's small pharmaceutical industry which had no difficulty in getting the collaboration of Oslo's medical and chemistry faculties would indicate the absence of industry-university links reflect a lack of need and tradition rather than ivory tower attitudes.

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To sum up, one may say that none of the five countries considers the state of its industry-university interface as ideal. It is true that in three of the five countries, industry-university links are probably stronger than in bigger countries, and even in Belgium and Sweden the situation is on the whole not less satisfactory than in France or the United Kingdom. However, this comparison is misleading; it is more relevant to compare a country's industry-university relations with its own needs and opportunities than with foreign models, and here clearly if the situation has ever been ideal, it is not so today in many countries. For small, highly industrialised countries which have to be competitive, the husbanding of scientific and technological resources is a need; they are too poor to afford the mistakes which bigger countries have made.

In Germany, student unrest paralysed one or two technical universities for some time without any noteworthy effect on the country's industrial, technological or scientific strength. The paralysing of the main technical university of Switzerland or Sweden over a similar period would be a national catastrophe. This means that care for the quality of the higher education sector, especially the technical universities, is indispensible if smaller countries want to keep their relative industrial and technological position in the world.

Chapter III

GOVERNMENT POLICIES TO SUPPORT INDUSTRIAL RESEARCH

1. The general climate

The efforts of the five countries to promote the industrial utilisation of science are one of the more successful chapters in the short history of "science policy".

In the formulation of their science and education policies, the five countries recognised the needs of industry relatively early, and made industry more than once a priority target of their research policy. This was partly due to the obvious trade dependence and economic vulnerability of all small highly industrialised countries.

The industrial research policies of the governments concerned formed part as much of economic as of "science" policy, which partly explains their success. Industrial research policies of governments have not developed in a vacuum; they must be seen as a part of the complex relationship between governments and industry. Although this relationship is not one of the subjects of the present study, a cursory remark on it may be useful. In general, industry-government relations in the five countries show distinctly different patterns. In Norway, which has a young and relatively small industry, and in Belgium, which has a very traditional industry, governments have shown strong initiative and will in industrial matters. In Switzerland and the Netherlands, which have strong, successful industries and a liberal economic system, governments often listen to the wishes and advice of industry and formulate economic policy accordingly. In Sweden, where both industry and government are strong and strong-minded, a more or less steady state of tension seems to have developed between the two.

Of course, all the peculiarities in industry-related research policies cannot be simply explained by the general state of the industry-government relationship of the country concerned. However, in some cases, links between general and particular patterns are visible. For example, the success of Belgian and Norwegian policies supporting industrial research reflects the strength of the government initiatives just mentioned, whereas the absence of any direct government support to industrial research in Switzerland must be seen in the framework of the relationship between government and Swiss industry which loathes government interference.

There is a second reason which explains why industry became a priority target for research policies in smaller countries: the absence of big power ambitions helped to keep science policy down to earth and diverted less attention and money to prestige or military programmes. Of all five countries, Sweden spends most on defence R & D, in absolute as well as relative terms. It is interesting to notice that Swedish defence research policy has more in common with the United States than with France or the United Kingdom: a large majority of all defence R & D is carried out by private companies which have already demonstrated their capability in civilian research and production. Probably this was profitable for industry as well as for defence procurement, contrary to the French or British policy which concentrated defence R & D in separate government laboratories.

In comparison with big countries, the industrial research policies of the five countries distinguished themselves in three respects, although not always in all three simultaneously; they started early, they were outspoken and conspicuous in all levels of science policy and therefore carried more conviction, and they were often directed by one institution or policy tool, and not fragmented into too many responsibilities. The relatively high status of engineering and industrial research in the public opinion of small countries facilitated such policies considerably.

This can already be seen in the composition of the national academy, the most senior representative body of science in a country. For example, the Royal Netherlands Academy of Arts and Sciences has several industrialists of not necessarily scientific background among its members, as a symbolic recognition of the contribution of Dutch industry to the progress of science. In comparison, one may record that in the United Kingdom, the applied scientists and engineers were very rare among the fellows of the Royal Society until the beginning of the last decade.

In Sweden, those traditions which appreciated pure academic research more than applied research seem to have been stronger than in Norway or the Netherlands, not necessarily among the public but certainly in the academic community. However, when the need arose, the Swedish system reacted quickly to make up for this difference. In 1919, after the economic difficulties of the first world war, the Royal Swedish Academy of Engineering Sciences (IVA), was created, partly thanks to industrial initiative. The new academy, modelled according to the Royal Academy of Sciences and not unequal in responsibilities, was a demonstrative and apparently successful attempt to raise the status of engineers and industrial research in the country.

IVA did not finance research; its main task was to propagate new ideas, to look into new fields of science and technology which neither industry nor university had yet taken up, to maintain international scientific and technological links through Sweden's science attachés in foreign countries, and to act as the main instrument of informal links between industry and university. In these functions and as a "think-tank", IVA has been a successful and original experiment. Since 1968, the Swedish Board for Technical Development, STU, which is run by the Ministry of Industry, is taking over those IVA functions which endeavour to draw industry and science together.

However, certain other countries still seem to need a similar independent institute of high status which might help them make up for the neglect of new fields by industry or university.

If we turn our attention from Academies of Science to Science Policy Councils, we find some of them include a considerable number of members from industry or from engineering and economic sciences. In the Science Policy Council of the Netherlands, the majority of the nine members are professionally competent to speak for or about industry. In the Central

Committee for Norwegian Research one of the 20 members is an industrialist, and 8 others are connected with either the technical university or industrial research institutes.

It is true that the power of Science Academies and Science Policy Councils is in some cases limited and in others non-existent. However, it would be wrong to belittle the possible influence of the presence of industrialists or engineers in those bodies. The world of science is very small in the countries concerned; such details as the professional background of the members of public science bodies not only reflect a general climate, but may also influence that climate.

2. The main policy tools to support industrial research

The "general climate" alone would not have been of much help, had it not led to the creation of executive bodies and to the formulation of policies to finance industrial research.

The Netherlands Central Organisation for Applied Scientific Research (TNO), of 1932, preceded the creation of a comparable fundamental research body by almost two decades. The Organisation for the Advancement of Pure Research (ZWO) was created in 1950, when it became clear that the promotion of fundamental research could not simply be left to the universities alone, as had been believed in 1932.

In France, when the Government created CNRS in 1938, it hoped that the new National Council would promote simultaneously fundamental and applied research. Today, CNRS and TNO run their own laboratories, but not much has been left of the applied research function of CNRS. Among its more relevant applied activities, CNRS administrates the "Salon des arts ménagers", the annual Domestic Equipment Exhibition in Paris, and collects its revenues— a bizarre survival of an early period of science policy. The contrast between France and the Netherlands leaves little doubt as to the research priorities which prevailed for a long time in the two countries.

The main— although not the only[1]— policy tools to support industrial research are as follows:

Belgium	*IRSIA*, created in 1944 (Institute for the Encouragement of Scientific Research in Industry and Agriculture).

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[1] It is not possible to analyse here all public policies and institutions which are relevant to industrial R & D. In *Belgium*, for example, it would be necessary to describe, after IRSIA, the following policies and institutions:

a) The Prototype Service (Ministry of Economic Affairs) which provides financial help for the development of new products;

b) The "National Programmes" which try to integrate fundamental, applied and technical research in specific sectors (e.g. in nuclear energy);

c) The Office of Industrial Promotion which helps to discover and to support science-based products (19 created in 1971);

d) Industrial Branch Research Institutes, the most important being the Centre of Metallurgical Research in Liège.

In *Switzerland*, the Commission for the Advancement of Scientific Research, created in 1944, is the main organisation to support industrial research. However, the budget and the means of action of this Commission are, for the time being, so limited that one cannot give it yet the same importance as is given to IRSIA, TNO, NTNF and STU.

Netherlands ..	*TNO* Industrial Research Organisation, created in 1932/35 (Central Organisation for Applied Scientific Research).
Norway	*NTNF,* created in 1946 (Norwegian Council for Scientific and Industrial Research).
Sweden	*STU,* created in 1968 (Swedish Board for Technical Development).

Although the structure, scope and financial impact of these institutions vary, they have in common their official status and origin as government institutions. This is a sign of government support for industrial and other applied research.

Moreover, with the exception of the Swedish STU, the above-mentioned institutions were created relatively early, changed relatively little during their approximately thirty years of existence, and concentrated much of the responsibility for public support of industrial R & D into one body. Tradition, continuity and concentration: these three factors made industrial research institutions focal points in the countries concerned. This was more difficult to achieve in bigger countries, where similar institutions were younger, changed more often and had to share their responsibilities with other institutions which sometimes belonged to other ministries.

Industry's reactions to public institutions for industrial research are not uniform. In Belgium and Norway they appear to be overwhelmingly positive; in the Netherlands reactions are often positive especially from big companies which use TNO, while criticisms can sometimes be heard from smaller companies; in Sweden the STU is probably too young to have had a deep impact, but its activities and expenditures are rapidly increasing and have stimulated considerable interest on the part of several industrial sectors.

Each of the four institutions has its own composition and pattern of action:

IRSIA in Belgium has no laboratories of its own, but finances research in industry and industrially relevant research in universities and other applied laboratories, mainly through individual fellowship grants. Its expenditures in 1969 excluding agriculture, amounted approximately to 6 per cent of all R & D in industry.

Unlike IRSIA, TNO in the Netherlands runs its own laboratories, specialised by industrial branch. The main, if not only activity of the TNO-Industrial Research Organisation is the carrying out of industrial research, which is partly paid for by industry itself. Since the TNO is subsidised by the government it can afford better and more varied specialisation and intrumentation than would be possible on a commercial basis alone. This makes it an attractive alternative for indoor research of large industrial companies in areas which would require unusual manpower or research tools.

In 1969, government support to TNO amounted to 3.4 per cent of all industrial R & D; all government support to industrial R & D directly to industry and indirectly through specialised R & D organisations such as TNO, amounted to 9.6 per cent of industrial R & D (in 1971: 12.7 per cent).

The Norwegian NTNF represents the most comprehensive and far-reaching solution to the problem of supporting industrial research, and combines nearly all imaginable, direct and indirect approaches under the same administrative roof. NTNF has 17 laboratories of its own in very different, mostly applied research fields, including nuclear research; it subsidises centres which work for industry, such as SINTEF, attached to the Technical University at Trondheim, or the Chr. Michelsen Institute in Bergen, and it distributes grants directly to industry or university.

Government subsidies to NTNF came to approximately one-third of all industrial R & D (1969). NTNF, by its size and all-round approach, has achieved a more powerful impact on industry than any of the other organisations. Thus, it was probably inevitable that NTNF should develop into a power centre in its own right, and provoke occasional criticism from other sectors of the research system.

The Swedish STU, created in 1968, concentrated the functions of several institutions, many of which had existed for some time: the Council for Applied Research, the Swedish Ore Foundation, the Swedish Inventions Office, and finally the Foundation for the Exploitation of Research Results and the Institute for the Utilisation of Research Results; the task of the last two bodies was to find possible applications for academic discoveries, in the same way as ANVAR (Agence pour la Valorisation de la Recherche) in France and the NRDC (National Research and Development Corporation) in the United Kingdom. This centralisation corresponded to a need for more coordination and rationalisation in government support of industrial R & D, a need that could be felt even in such an industrially strong and well administrated country like Sweden.

Once again, small size appears to be an advantage: the creation of STU, entrusting one single body with all public support for industrial R & D, except in military fields, certainly looks very rational in comparison to the situation in France and the United Kingdom where ANVAR and NRDC, among others, are independent of other public efforts to promote industrial R & D. Ought those countries to concentrate all their public activities related to industrial or applied research into one giant ministry however? The experience of the now dissolved Ministry of Technology in the United Kingdom will have left some doubts behind; as from a certain size, concentration does not always lead to co-ordination.

STU's main activities are at present: to provide assistance to R & D projects initiated by industry or universities; to represent the government in the financing and running of industrial branch research institutes; to stimulate R & D in areas of society where such efforts are underdeveloped; to promote innovation in small and medium-sized companies, in universities and among "free inventors", and finally to carry out long-term studies, and information and documentation activities.

Unlike the Dutch TNO or the Norwegian NTNF, STU does not run big laboratories of its own, although on the whole its activities are broader than those of TNO or IRSIA in Belgium. In 1969 government subsidies to STU represented approximately 8 per cent of all industrial R & D.

In Switzerland, the Commission for the Advancement of Scientific Research has the objective of supporting industrial research. Its budget is slim, however, and amounts to only 0.1 per cent of all industrial R & D; in addition, its impact has been limited because in general it has financed applied research outside industry. However, industrial research in certain branches has received for some time support from the Commission for the Advancement of Scientific Research, by means of contracts which universities give to industry. Since industrial research as such is not considered in Switzerland as a cause for direct subvention, the Commission tries rather to take industrial needs into account in supporting university research and to encourage collaboration between industry and university. The strength of most of Swiss industry, and its desire for independence until recently made direct government support not only superfluous but politically impossible.

The attitude of certain industrial sectors is now changing, but in the past Switzerland had mainly an indirect policy means to support industrial research; its effectiveness should not be underestimated however. It consisted of the steady and exclusive solicitude of the Swiss Confederation for the Federal Institute of Technology (ETH), and its annex-institutes for applied research.

With the exception of Switzerland, the proportions of financial support for industrial research are not insignificant. Eight per cent, 6 per cent or even 3 per cent of all industrial R & D are sums which, if not scattered too widely, can initiate or help more than one project.

However, it is neither the financial proportions nor the official range of activities which reveal the full impact of those policy tools in the countries concerned. This is especially true of IRSIA.

In fact, IRSIA, TNO, NTNF and STU, together with IVA, have become major clearing houses for knowledge on industry and university, and indispensable instruments for the forming of formal and informal links between the two sides. In principle, the small population size of the five countries should facilitate informal links between industry, university and government, which are such an important condition for an efficient industry-science-university interface. This was true in some countries but in Belgium, and to some degree Sweden, socio-cultural and geographical factors respectively have put obstacles in the way. In all the countries, the existence of public bodies which knew industry and university well, and gathered both sides to research commissions and meetings, proved to be very valuable.

In relative terms, that is, if the starting point of the countries concerned and the distance they had to cover are taken into consideration. IRSIA in Belgium was an outstanding success in this respect. Not only did it bring industry and university together in many cases, but it pushed an often conservative industry to start new projects, to look a little bit more into the future and to perform some fundamental research beyond the needs of the day.

One of the most important tasks of industrial research institutions is the direct or indirect provision of R & D facilities to smaller industrial companies which cannot carry out all their R & D in their own laboratories. In other words, the industrial research institutions perform most of the function of the Industrial Research Associations in the United Kingdom, the Centres techniques professionnels in France and the AIF (Community of Industrial Research Associations) in Germany. The Industrial Research Organisation (TNO) is an association of several industrial branch research institutes, while NTNF, STU and IRSIA have a more indirect approach, providing financial support and occasional guidance to industrial branch research institutes. In this activity, the industrial research institutions seem to have been successful, at least if certain positive reactions in smaller countries are compared to the complaints about industrial research associations in bigger countries. There are probably several reasons for this success.

The idea of linking industrial branch research institutes legally or at least geographically to technical universities where they could find a firm scientific and administrative basis may have been decisive.

However, it is sometimes the big and not the small companies which collaborated most with the branch research institutes and the laboratories of applied research organisations. Hence, big companies profited at least as much from this type of indirect government support to applied research as small companies.

The governments concerned intended originally to help the small and medium sized companies rather than the big ones, but it now appears that the smaller countries were not much more successful in bringing science to small industry than the big countries. TNO in the Netherlands, for example, has been severely criticised for this, but it is not always easy to judge where responsibility for such failure lies. Too much independence and not enough initiative on the part of applied and branch research institutes may have worked together to reduce the relevance of the institute's work to small industry. An initial misconception of the needs of small industry may have created false hopes and consequent frustration on both sides: small industry needs the diffusion and adaptation of well known technologies and some trouble-shooting more than research.

Certainly, finally, the attitude of small companies has not always been beyond reproach. If companies fail to understand the need for and advantages of co-operation in R & D or other activities, then branch research institutes, whether government or industry financed, will often find life difficult. The Swiss Laboratories for Watch Research in Neuchâtel are among those who have witnessed the truth of this more than once.

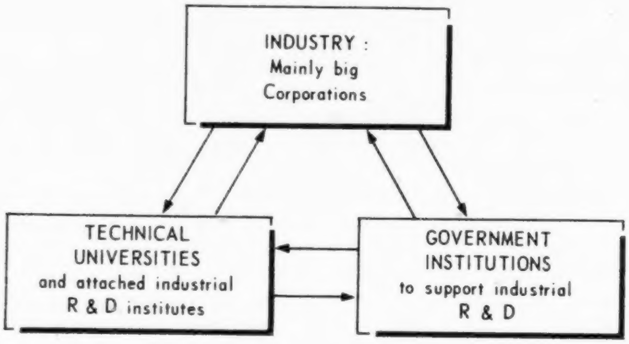
3. Summary and conclusions: towards a technology policy for the future

Three special factors— apart from the more general ones— explain the strength of the industry-science-university interface in the five countries concerned in this study: big, often multinational companies in science-based sectors, technical universities and the attached industrial research institutes, and successful government policies and institutions to support industrial R& D.

These three factors are not equally strong in all five countries. Whereas the biggest multinational companies can be found in the Netherlands and Switzerland, central technical universities with a clear industrial mission exist in the Netherlands, Norway, Sweden and Switzerland. The relatively most effective government institutions to support industrial research were created in Belgium and Norway, and to a smaller degree in the Netherlands and Sweden.

Thus, there seems to be a sort of compensation among the three factors: a country that is lacking in one factor will try to make up for this disadvantage by reinforcing one or both of the two others. In fact, the three factors did not develop independently; in the preceding pages many links between them have emerged.

The links between the Netherlands, Norway and Sweden may be shown as follows:



In this triangular "system", there is continuous personnel and financial interaction among the three factors normally benefiting all participants. The relative strength of the links or "arrows" between factors varies considerably and also according to country. For example, as mentioned above, in the Netherlands the research directors of four of the five multinational corporations are graduates from the Technical University Delft. The big corporations remain in close touch with Delft and with TNO which has its industrial laboratories on the Delft campus. In Sweden, the big companies remain in close contact with the technical universities and their attached industrial branch research institutes subsidized by STU. Many other examples could be given in the other countries.

This system looks like the execution of an intelligent long-term plan to raise the technology level of countries with limited resources and to guarantee them a strong industry-science interface. A most unexpected aspect of the system however is that it was not planned in advance, even not by industry which stood to gain most from it. The system resulted from the concording will and common sense of people in industry, university and government with the same national aims and a similar educational or philosophical background.

It would be difficult to find anything comparable in the bigger countries, at least as far as the industry-science interface is concerned.

Other details also reveal this element of common sense and adaptability within a system that has not been planned. In particular the public sector of the five countries have adapted well to the changing needs of industry and industrial research except for the technology problems of small industry, which remain to be solved.

For example, one finds in small countries collaboration between Ministries of Industry, Science and Education and Science Policy Councils, which is no mean achievement. Since the Ministries of Industry are usually financing the applied research organisations, coordination is necessary to avoid duplication, contradictions and competence fights. After some initial tensions for example, in Belgium, which are now largely overcome, small countries seem to have reached a more effective measure of inter-ministerial co-ordination, at least between their economic and science ministries than France or the United Kingdom.

The question is whether this adaptability of the public sector, industry and the university will suffice in the future. First, the past success of industry and technology in many small countries was due not only to research. This should go without saying, but it may be forgotten in a study on industrial research. The professional quality and devotion of the industrial labour-force, especially in the Netherlands, Sweden and Switzerland; fewer labour problems as compared to the big countries; the remarkable competence of "simple" technicians in industrial research and development; help from efficient banking systems; the absence of war in Sweden and Switzerland, have all played a part, together with R & D, to make industry successful. Today, the feeling prevails in some of the five countries that concerning many of those functions, the distance which separated them from other countries is shrinking.

Simultaneously, new problems which directly concern the industry-science interface and the triangular "system" are emerging. Several have been broached in this report: possible difficulties in trying to "kill two birds with one stone", in other words to merge fundamental and applied research into one, possible tension between multinational company strategies in R & D and national science policies, a possible decline in the pertinence of technical universities.

In spite of their apparent disparity, these problems are related. Can their solution be left to the adaptive forces of the triangular "system" which proved their efficiency so often in the past? The increasing complexity and interrelation of all factors, the interference of new and often unforeseen elements, such as environmental problems which could concern the small and highly industrialised even more than the big countries, the need to take an increasing number of far-reaching political and foreign trade decisions which affect industry and technology— all lead to the conclusion that some of the smaller countries will require in future a more co-ordinated and deliberate approach: in other words, a technology policy beyond the triangular "system".

Technology policies may have global or sectoral aims. In both cases, the first steps of a technology policy are the formulation of specific goals and a definition of the means to achieve them. A global technological policy, for example, could set as an objective for the five countries concerned the maintaining of their industrial, technological and scientific position in relation to bigger countries. This probably would imply the setting of industrial and scientific priorities at national level. As far as can be seen, Japan seems to be the only industrialised OECD country which has developed a technology policy with global aims. None of the five countries seems to be ready for such a global policy, either politically or administratively. But some of them have shown the will and ability to carry out sectoral technology policies. Certainly, Sweden's defence procurement policy is a sectoral technology policy with clear long-term aims, involving industry, university and government. The information available suggests that Norway is indeed moving in this direction.

In any case, whether technology policies are global or sectoral, they require within the government sector the co-ordination and ideally the integration of all industrial, science, university, foreign trade and environment policies which affect technology. Until now, these policies evolved independently, often reflecting a political situation based on compromise, competition between conflicting political parties, or conflicting opinions within one party. Moreover in countries where universities and industry retain a considerable degree of independence, technology policies may require a much closer inter-action between industry, university and government.

The achieving of this coordination and the defining of long term national objectives without giving up political freedom, may be one of the main challenges for many of the smaller countries in future years.

Part V

THE PLACE OF THE FOUNDATIONS IN THE RESEARCH SYSTEM

by
Maurice FLORY

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INTRODUCTION

The word "Foundation" must not here be interpreted in any too narrow legal sense, nor is the relevant legislation necessarily the same in all countries. The term should be taken to cover all forms of private financing for research through independent organisations. To quote the definition adopted by the directors of some of the most important foundations in Europe, "a foundation can be described as an independent, non-governmental, non-profit-making organisation, managed by its own trustees or governors and so organised as to allow creative action and to make an objective and professional assessment of its field of activity".

By combining a flexible legal criterion with a material criterion, we can define the type of foundation discussed in this paper as any organisation whose rules allow it to receive private funds, especially donations and legacies, which can manage them freely with favourable tax and legal treatment, and which is free to take the initiative in allocating its funds to research programmes.

The origin of foundations is several centuries old; most of them were designed for charitable ends or were devoted to teaching, art or culture; only in much more recent times, as research grew in strength over these last twenty years, have foundations old and new become science-oriented. Only those which allocate at least part of their resources to scientific research are studied in these pages.

This new role has been a factor in promoting their remarkable expansion and in bringing the whole subject of the foundations into the limelight.

The freedom conceded to private initiative has given birth to foundations in such variety that it is hard to devise any way of classifying them. If we confine our attention to research, however, there are a few distinctions we can propose to make the subject clearer. Looking first at spheres of activity, foundations which cover but some specific scientific sector, such as medicine or pharmacology,[1] or are even more narrowly limited to a particular disease such as leukaemia or cancer[2] can be distinguished from others active in several areas of science.[3] In practice, however, no foundation can ever be entirely all-embracing even though its statutes may prescribe a general role: however powerful it may be it cannot cover everything and will therefore tend to select particular sectors, and to launch or support specific activities within these sectors.

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[1] Such as the Fondation pour la recherche médicale française, the Mario Negri Foundation, Italy.

[2] Such as the Lady Tata Memorial Trust (India, United Kingdom).

[3] Such as Agnelli (Italy), Stiftung Volkswagenwerk (Germany); Ford (United States).

The *geographical* dimensions of the foundations must also be considered; some play a purely local or regional role and are designed to support scientific research in one university; the field of action of others takes in the entire country of origin; others again are international in scope, either because they support programmes which have a worldwide scientific impact, or because their activities extend to financing foreign science and research programmes beyond their own frontiers.

In the matter of *methods of action*, grant-making foundations, which do no more than provide grants and scholarships without having any programme of their own in the strict sense, can be distinguished from operating foundations, which are much fewer in number, have their own scientific advisers, programmes, administrative departments, research teams and sometimes even their own laboratories.

The *origin of a foundation's financial resources* is an important factor in that it largely determines what the foundation does. Some foundations rely mainly on funds raised among the public; these depend heavily upon the success of promotional campaigns and upon their public image. The Foundations Centre of New York considers that "fund-raising organisations" should not be counted as foundations, although this seems rather too arbitrary an attitude since some of these obtain only part of their resources from fund raising and are active in the same way as the others; an example being the French Fondation pour la Recherche Médicale, which hence can hardly be excluded. In addition to public fund raising there are four other possible sources of money. First, the initial endowment provided by the individual who sets up the Foundation; the "Directory of European Foundations" notes that only half the foundations it lists draw their major resources from such endowments. There are foundations set up by industry which receive large annual payments from their company of origin; this applies for example to the various CIBA Foundations, the Swedish Foundation for Famine Relief and the Agnelli Foundation. Others, such as Stiftung Volkswagenwerk of Krupp, may receive dividend income as holders of some proportion of the shares in the company which founded them. Lastly, many receive grants, sometimes very substantial grants, from the State.

At first sight, it is not easy to grasp how these foundations fit into the research system. It is hard to see what objectives even those which are world-famous have set themselves, and what effective part they play in furthering research. The attitude of some governments makes one wonder what real value foundations can have for research. A country such as France manages almost entirely without them. What future can they have, now that the euphoria of the post-war years is over, when it is common knowledge that research costs nowadays are mounting ever higher, and that even the vast resources of a national budget are no longer adequate? Has the era of private research come to an end? And if there is still an independent sector, is it not wasteful to allow programmes which are bound to be costly to escape national planning at a time when we seem to be entering a period of scarcity?

To answer all these questions it is clearly necessary to examine the quantitative and qualitative status of foundations before considering how they can be made to play a useful role.

Chapter I

QUANTITATIVE AND QUALITATIVE EVALUATION OF THE ROLE OF FOUNDATIONS

It is clear at the outset that research expenditure by foundations accounts for but a tiny fraction of total research expenditure. Even then it must be remembered that the situation varies from one country to another, and in different research sectors in the same country. In view of the widely differing situations it is difficult to measure precisely the quantitative role of the foundations; suitable instruments are still lacking which would make it possible to keep a regular check on their contribution to the research system.

1. In assessing the role of the foundations it would be helpful to compare their financial weight with the wealth of the appropriate country. There are several possible yardsticks, such as the percentage of GNP represented by the wealth of the foundations or foundation assets per head of population. At this point it is not necessary to isolate the research-oriented foundations from the others; an approximate overall figure will be enough to provide a reliable indication of the climate and national environment in which foundations are able to exist and work. The fact that foundations have assets of $105 per head of population in the United States, $58 in Denmark and $33 in Germany warrants the inference that a country such as the United States offers an especially favourable environment for foundations. These indications provide a better insight into the existing discrepancies and into the realities which govern the growth of research foundations in any given context.

2. In assessing the part which the foundations play in financing research, evaluations by sector will be more enlightening than an evaluation of their overall contribution. In percentage terms the financial contribution by foundations to the overall "system" is certainly very low; but percentages mean little— in certain fields (e.g. nuclear and space research) it is close to zero, while in others it may be substantial or even preponderant.

Medical research provides a good example. The proportion of private aid varies considerably from country to country: from $0.14 per head in France, $0.75 in Sweden, and $1.16 in Britain to $5.40 in the United States. In Britain the volume of private and official funds allocated to medical research is the same, the amounts are scattered among a great many foundations, which enjoy considerable freedom and low staff commitments. In Italy, most pharmaceutical research revolves around the Mario Negri Foundation, whose role is thus very important.

3. In order to understand how a foundation functions it is necessary to know what resources it has and how it uses them. Capital must be distinguished from annual incomes and it is necessary to know the breakdown of the annual budget by sector, including management costs. In view of the international scope of many foundations, their transnational activities must be assessed by looking at their expenditure outside their own countries.

There are a few dozen foundations of world importance: the most and largest are found in the United States and their drive and methods are a model for European foundations. There are considerable differences in size: the Ford Foundation, which is the largest in the world, has an annual budget which exceeds that of the Centre national de la recherche scientifique in France. This giant has more than three times the resources of the Rockefeller Foundation, which is the second largest It is 45 times the size of the largest British foundation, the Wellcome Trust. The role which a foundation can play obviously depends to a great extent on the resources at its disposal, yet even a small foundation when wisely directed, can play a substantial secondary role: and if it is specialised, its modest size will not prevent it from exercising some appreciable influence in an appropriate field.[1]

Even a very thorough statistical investigation can give no exact idea of the role of foundations, except in some privileged sectors such as medicine; it can only bring out the modesty of a contribution which is often very dispersed. It is therefore from the point of view of quality that the action of the Foundations becomes significant.

A foundation can fulfil a unique mission in so far as it enjoys relative financial, administrative and scientific independence. But this is not always the position. Governments sometimes use the foundation technique to provide themselves with a more flexible instrument than they have in the civil services, which are always bound by strict administrative and financial rules; in these rare cases it is the Government which finances and in addition also runs the institution through a board whose members it then takes care to nominate. This type of establishment may be valuable, but it is no more than an instrument at the disposal of the state.[2]

Financial independence presupposes other than official resources, a situation which is difficult to maintain over the years; as a rule, the original endowment soon becomes inadequate, owing to currency erosion, the rising cost of living, or a decline in the value of stock-exchange investments. It is not easy to find fresh resources unless the foundation is linked to a large firm which has retained the option of regularly pouring in new money. In such an expensive activity as research finance remains one of the most difficult problems for the foundations, which are compelled to abandon overcostly lines of research unless they are prepared to co-operate with the official sector, with the disadvantage that at least part of their freedom is then lost.

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[1] Some foundations are limited to very circumscribed fields, such as the Lady Tata Memorial Trust, (India, United Kingdom) which is devoted to research on leukaemia; the Hasler Works Foundation (Switzerland), which is designed to promote the development of telecommunications in Switzerland.

[2] There are two situations to be distinguished. The State may have taken the initiative in setting it up (e.g. the Fondation de France), or it may have taken over a foundation which has run into difficulties (e.g. the Institut Pasteur).

The *administrative independence* of the foundations varies according to country and depends on how the Board of Governors is constituted and on its freedom of action. As a general rule although the foundations come under private law and are managed independently of State interference, they nevertheless come under searching scrutiny from the authorities owing to their charitable and mortmain status. This control starts as soon as the foundation is set up, with the requirement of standard statutes and the approval by the authorities; it may be carried further by obliging the foundation to include on its board a number of representatives of the public interest, to apply for permission to accept gifts and legacies, to have its activities checked for conformity with the aims laid down in its statutes and to submit to many types of tax inspection; precise rules must be followed for the disposal of property in the event of the foundations dissolution. Although these interventions by the authorities and administrative procedures may appear burdensome since they impose formalities and consequent delays, in fact they substantially affect the foundation's freedom of action when it deliberately accepts State control by giving it a majority on its board.

Administrative independence is not by itself enough to guarantee *scientific independence*, which becomes all the harder to preserve when coordination with official research is necessary. There is then a strong temptation to bring individuals responsible for government science policy into the bodies of the foundations which decide on programmes. The foundation then runs the risk of not being able to break free of official orthodoxy.

In so far as a foundation remains independent of the authorities, its specific character may be asserted in many different ways which can be grouped under five heads.

1. A complementary function

Research has become so expensive an undertaking that no country can afford duplication of effort. It is however reasonable that private finance should try to fill the gaps left by the public sector when there is some scientific merit in so doing.

It can consist in some ancillary financing, extremely helpful, even though it accounts for but a small percentage of the entire amount. The foundation can make good some of the flexibility which is lacking in publicly financed research. Research must always be at odds with administrative rules; governments realise this and have gone to a great deal of trouble to streamline procedure. The administrative rules of the CNRS are not the same as in ordinary public departments; scientists are not exactly civil servants and resources are managed more flexibly, yet experience shows that the natural inclination is to go back to the orthodox administrative rules. Everything favours such a trend— the habits of some of the managers recruited from among senior civil servants, the financial control, the conservatism of the staff associations, etc. In all countries, and in some more than others, publicly financed research meets obstacles in the rules for public accountancy, in administrative delays, in hierarchical red tape and can easily get bogged down. The foundation can then help most effectively by bridging gaps, averting sudden halts and preventing interruptions which can sometimes result in a project having to be abandoned in midstream.[3] One cannot fail to be impressed by the number of beneficiaries of the Nuffield Foundation which makes hundreds of grants every year in every discipline, in Britain and the Commonwealth, in the same way as the CNRS Commissions in France, but with the difference that this private aid fills gaps which the State has left or reinforces action it has taken; while the French scientist has nowhere to turn after some negative or inadequate decision by the CNRS, his equivalent in Britain can try his luck with one or several foundations.

Lastly one should consider the especially important role which the Foundations can play during some critical period generally affecting both university and public sectors of research. In Britain and the United States, the many richly endowed foundations can take over in some sectors. Italy seems to have understood this and during its present troubled period is trying to encourage the creation of foundations and their activities.

This initial form of complementarity is essentially a "stand-by" service: the foundation can be regarded as an extra fail-safe circuit coming into operation when the original circuit malfunctions. The path of research is liable to be thornier in a country with no such device.

There is however another complementary function which is harder to fulfil since it is the foundation which has to take the initiative in spotting it. Such an opportunity may arise when the State holds back from research in particular fields, for political, economic, administrative, ethical or other reasons, with the result that they are deliberately or unconsciously ignored. These are just the kind of research areas for the foundation normally to take up.

A serious political difference, open conflict or war with another country may threaten an end to official research in a particular geographical area. A foundation will feel much freer to gamble on the future on the chance that the difference will one day be settled and that it would then be a pity not to have prepared for recovery by pursuing and even stepping up investigations undertaken in the country concerned. It is thanks to a large American Foundation (the Ford Foundation) that Chinese studies have not been interrupted and have even made considerable progress, since the Communists came to power in China. The advantages to the United States today are plain to see. Thus, the foundations constitute a counterweight to the political and ethical trends of the moment; they avoid investing in the more popular fields and rather seek out those which have been temporarily ignored or forgotten.

This function of sectoral complementarity is a mark of both the international and pioneering role of foundations.

2. A decompartmentalising role

Scientific research needs to be wide open to the outside; there should be constant communication between scientists, between laboratories and between countries and, whenever possible, between one discipline and another.

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[3] See correspondence quoted in a booklet of the "Fondation pour la recherche médicale française", June 1970, pp. 17-23.

In seeking to broaden the frontiers, foundations have played a far from negligible role in helping ideas to spread. They have, for example, done much over the last 20 years to make Italian culture less narrowly provincial. Foundations in all countries are prepared to take up areas of research which, because they do not fit into any one category of specialisation are liable to be discriminated against because of the way the disciplines are kept administratively separate. The Wellcome Trust in Britain, for example, has supported veterinary research, which relies on both medicine and agriculture; it has also tried to increase links between clinical and basic sciences because there is a tendency for basic sciences such as biochemistry, to develop in isolation from medicine and other applied fields.

As private institutions, foundations are better placed structurally than the State to engage in transnational activities. For example, any research possessing an international dimension sets a government problems which can be difficult to solve. Scientific co-operation between governments, essential though it may be, makes slow progress, following procedures whose clumsiness is increased by the number of countries involved, since international agreement is necessary to decide upon and to organise any operation of this kind. Space and the nuclear sciences are obviously not fields in which private finance can be expected to do better than the State. But in many other sectors the foundations have a clear-cut international function and have often a better chance of succeeding than governments, whose continuing co-operation is always hypothetical. As private and independent legal entities, there is nothing to prevent the foundations from crossing frontiers, establishing themselves outside their own territory, recruiting scientists of every nationality, financing foreign projects, setting up co-ordinating structures to implement programmes on an international scale. As private and independent legal entities, normally nothing should prevent the foundations from crossing frontiers. But often statutory provisions and the national tax laws require that the foundations spend most if not all of their income in their home country. Therefore, only few of them have succeeded in establishing themselves outside their own territory. There are research projects in France paid for by German or American foundations, whereas with a few rare exceptions the CNRS justifiably disclaims competence to support a foreign project or to provide a grant for a foreign scientists working in his own country.

International institutions, especially the United Nations Development Programme, recognise this international function of the foundations by assigning economic development studies to some of the larger foundations (an example is the role of the Ford Foundation in studies for development of the Mekong Basin).

At a time when European unity is being built up, the foundations are actively contributing to what might be called the Europe of Science. Close links have been created between some of the directors of the major European foundations; one constantly recurring objective of their programmes is the circulation of scientists; what amounts to a European network of medical research for example, has been set up thanks to Rockefeller grants.

Against the background of decolonisation and the birth of new sovereign states, the foundations have deliberately set out to temper the effects of the new partitionings. In Britain for example the Wellcome Trust has initiated a substantial research programme in tropical medicine at a moment when official British efforts in this sphere were slowing down, and the new States were not yet ready to take over.

3. A pioneer role

Flexibility of management, speed of decision and the contractual status of salaried staff enable the foundations to take a more forward-looking attitude and to act faster and with greater boldness than official research bodies. To their complementary function they add a role of innovation which is of crucial importance in an area where constant alertness and a state of permanent renewal are essential.

Many examples can be adduced to their innovating role. The foundations were the first to deal with family planning, not being inhibited by a taboo which officialdom dared not challenge. After breaking the ice in industrial societies, they are now trying to spread the idea in the developing countries, a much more difficult undertaking. The famous "green revolution", which has increased agricultural yields in the developing countries, is very largely their work.

The foundations have played a very important part in developing research in the social sciences: the technocratic machine which the modern industrial state has become is mainly interested in an economic return, and the exact sciences, which can always offer prospects of economic application are constantly put first. The official research authorities attach a great deal of importance to inventions and new patents for their balance sheets and annual reports. It is obvious that findings in the human sciences cannot be evaluated so easily, but is it right to infer that they are hence less profitable? When one considers— to take just one example— the tragic result of ethnic conflict, whether in the Third World or the prosperous countries, there would be less hesitation in financing research in the human sciences. The foundations, which seem to have grasped this fact earlier than official research agencies, were among the first to deal with racial problems in the United States, with segregation in everyday life, with housing, with the social effects of urbanising the environment, and generally speaking with that whole area on which social harmony depends, generally known as "community welfare".

Research in this area has in the main been interdisciplinary, affording yet another opportunity as we have seen, for the foundations to break new ground by setting up suitable teams for such a task.

The American lead in this, as in many other fields, has induced the large foundations on the other side of the Atlantic to help European countries to make up a lag which the public authorities on the spot, faced with so many other problems, could not immediately remedy. The Fondation nationale des sciences politiques set up in France under the will of André Siegfried has, with help from the Ford Foundation, pioneered the development of political science in France. The first research in the human sciences by developing countries has often been undertaken at the instigation of foundations abroad: an example is the Centre d'études et de recherches économiques et sociales in Tunis, supported by American and German foundations.

A foundation can do pioneering work more easily than a government agency, because it can take greater risks. If the scientific bodies of a foundation are carefully chosen and given the proper incentive, they will look for new lines of research and adopt a bold forward-looking approach.

Today's social crisis in the industrialised capitalised countries would appear to offer the foundations new avenues of research. It may be asked whether the foundations retain the liberty and independence required in a search for new alternatives. Carnegie gave the foundations which bears his name the objective of "creating the orthodoxy of tomorrow by promoting the heresy of today". What he said then appears strikingly relevant in our period of restless protest, and helps to explain how conventional opinion will sometimes fail to understand a particularly daring approach— and how this kind of "anti-establishment" attitude may cause suspicion and lead to the creation of so many committees to investigate foundations set up in the United States.[4]

The foundations cannot swim against the tide for very long; they are obliged to "sell" the orthodoxy of tomorrow and to do this, since their resources are weak, try to provide the leverage which can alter the situation.

4. Providing the leverage

Even limited resources, provided they are wisely laid out, can influence the orientation of this or that sector of research.

Clearly, the quantitative aspect cannot be disregarded; leverage presupposes a certain weight and certain dimension. The wealthier the foundation the more it can hope to affect the trend of official research. It is also clear that such action has little chance of amounting to anything in those areas of science which are so costly as largely to rule out private enterprise. But even here some carefully chosen project can have an appreciable impact: while foundations play no very great part in space research, their initial role in the development of rockets should not be forgotten. Furthermore, they are always in a position, to award grants to encourage scientists in certain directions without having to support the research itself.[5]

In some cases then, the foundations appear to act as a standby structure. A successful experiment may convince the authorities that it would be well to orient research in some new direction. This has certainly been the case with some educational research programmes; the studies which originated the movement for renovating higher education were started by the American foundations before being taken up and financed by the authorities. In the same way, the foundations forestalled the authorities in tackling the schooling and integration of ethnic minorities or of immigrant children; and this may help to explain why a country such as France, which lacks the support of private research, has lagged so far behind. Massive support from the Ford and Rockefeller Foundations enabled the "Sesame" project to be launched and thus heralded the beginning of educational television for very young children. Because the social sciences were less generously endowed than other branches of research, the large Swedish

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[4] See A. Kirchberger: *Foundations in the United States*, La Documentation Française, Etudes Documentaires, 1973. *Note on Foundations in the United States*, M. Pmey, NED, No. 3334, 5th November, 1966.

[5] The Fondazione Angelo Della Riccia (Italy) thus exclusively promotes the study of nuclear physics by making grants to Italian students.

Foundation set up for the tercentenary of the Bank of Sweden decided to allocate approximately half of its resources to social science research. The grant at first amounted to three times as much as the official budget allocation, and the ultimate outcome has been that the State has increased it. In France some connection can be noted between the activities initially undertaken by the Fondation pour la recherche médicale française and the growth of official finance for this branch of research. At European level, the Volkswagen Foundation initiated research in molecular biology by supporting the European Molecular Biology Organisation (EMBO) during its first years.

Some foundations (in particular the Agnelli Foundation), seeking to achieve an entirely convincing demonstration and to facilitate the transfer process they hoped for, have even gone so far as to recruit and provide temporary facilities to scientists, setting up new research teams and generating new research structures. In this way, ready-made teams have been formed, have proved their efficiency and the value of their approach, thus showing that such a scheme is workable and can be adopted by the public sector. Two teams of this kind are functioning in Italy, one concerned with the political social structures, in particular the study of attitudes and tendencies among the ruling classes both in themselves and in relation to socio-cultural realities; the other is studying managerial groups, contacting more than four hundred businessmen every year. Over and above the particular project involved, this type of operation is of interest from the standpoint of research methods and concepts.

5. Influence on the whole concept of research

Government-backed research institutions naturally tend to become ossified and their staff to become bureaucrats, while the foundations, untrammelled as they are by administrative rules in their operation and in the management of their staff, can remain enterprising in outlook and unfailingly receptive to new ideas. In an age of planning and of centralising technocracy, they are an oasis where the kind of freedom increasingly recognised as essential, can be practised and they contribute a pluralistic element which is a guarantee of independence. As has been rightly said: everything suggests that in the relationship between science and the state, the era of laisser-faire has practically disappeared; but there are some signs that the end of laisser-faire may also mean the end of freedom to innovate. By willingly listening to the proposals of scientists owing to their open attitude towards every kind of innovation, their freedom in comparison with the ukases of officialdom, their regard for decentralisation, as shown by the interest some of them take in local communities and decentralised decision-making,[6] the foundations constantly renew the approach to the whole concept of research and a drive which seeks to satisfy the requirements of efficiency and a deep feeling for the democratic process.

Independent research, which must constantly meet new challenges and justify its existence, pays especial attention to its public relations. The foundations publish annual reports which are often widely circulated and in a country such as the United States, where they carry considerable weight, they join forces to inform the public more effectively and at the same time keep a mutual check on their internal probity.[7] This relationship with the public enables the foundations to promote an awareness of present-day problems, so that people can more easily agree to the demands which may be made upon them by the authorities; what the foundations have done in educating the public in regard to such matters as racial conflict, family planning and drug addiction, to take only a few outstanding examples, is well known.

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[6] P. Lindblom, *The Bank of Sweden Tercentenary Fund*, Stockholm, 1963, p. 52.

Foundations with small endowments which are financed by regular contributions from the public have an even more pressing need for good external relations. This applies to the Fondation pour la recherche médicale française, which depends on many people for funds and thus co-ordinates private research in its field.

The dynamic and liberal conception of research which the foundations endeavour to promote is bound to have an effect upon the authorities and upon officially organised research, quite apart from its own research results, through the quality and originality of its style. It represents, as we have seen, a testing ground which can take greater risks and find new paths. It helps the community to a better awareness of what responsibilities ought to be undertaken in the field of research.

In this appraisal the emphasis has deliberately been placed on the positive and original aspects of work done by the foundations. It would be wrong to infer from this favourable picture that the foundations experience nothing but success. Like every human undertaking, they have their share of setbacks; if matters were otherwise they would in fact be shown to be lacking in boldness, the worst fault for which they could be criticised. Since their problems are not those of official research bodies, the foundations can avoid certain difficulties which impede the authorities. Conversely, they may encounter obstacles which they are incapable of overcoming. Each foundation has its own characteristics and operates in a particular context. It is therefore difficult to construct a model for analysing the typical role of a foundation in research. What one can try to do is to show how problems facing the foundations are dealt with.

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[7] The Russell Sage Foundation— jointly with other big foundations— has set up a documentation centre, the "Foundation Center", which publishes regularly a "Foundation grants Index" which is a record of foundation grants of $10,000 or more by fields of activity.

Chapter II

PROBLEMS FACING THE FOUNDATIONS

How does a foundation whose overall purpose is to encourage scientific research decide what form its intervention should take, draw up its action programme and select the recipients of its grants? However independent the foundation may be when engaging in research it is bound to run up against the State, which plays a preponderant role; the relationships built up with the State are bound to have a decisive influence on what the foundation can do; they will also reflect the State's general philosophical approach and its role in the life of the community. The foundations are a part of that community; they are the work of the people who live in it and an instrument which they are meant to use.

The independence of foundations, however, renders them vulnerable to criticism. It would be surprising and even disquieting were their actions to be always accepted without question. In fact dissatisfaction may arise from three different sources. First, the scientists themselves may be opposed to activities which escape the control they exercise by being represented in official bodies. Next, the foundations are often the target of political criticism; they may be accused of trying to change society too quickly, as they were during the McCarthy era in the United States; or as partisans of reform they may not please those who are at odds with the whole system and would like to see it destroyed and replaced by a new society. Finally, the foundations may arouse the suspicion of such political institutions as parliamentary bodies, the executive branch or civil service, for not submitting to their control. It is therefore important to find out how the foundations may reply to these criticisms and organise their relationship with the community and with public opinion.

1. The foundations and research

The first problem is that of scientific orientation and choice of programmes, where the decisions lie with the board of governors or with the scientific council which is answerable to the board. A foundation is not in fact free in the absolute sense; fortunately the foundation and the scientific community must be interdependent; each needs the other, while respecting its autonomy. Every foundation eventually acquires its own "brand image", and its special field is known to the appropriate scientific circles. It is well known in Italy, for example, that the Olivetti Foundation is interested in regional studies, particularly those concerned with development, and that the Agnelli Foundation studies the evolution of industrial society, while the Einaudi Foundation is interested in financial, monetary and banking problems, and the Cisci and Lerici Foundations deal with art and archaeology. The foundations are hence constantly approached and stimulated by the scientific community; they are therefore obliged to screen, select and plan, or in a word determine what their policy is to be.

Two attitudes are possible in theory: the foundation can seek to have a research policy of its own. Among the factors which must then be taken into account are, first, its statutes, which may sometimes point in a very specific direction, then the material sources at its disposal, which will impose certain limits; finally national science policy cannot be ignored, and must be considered in the light of a complementary or innovatory approach. The other attitude is entirely pragmatic, and consists merely in reacting to national science policy, any worthwhile directions being dictated by expediency.

In practice, the foundations will begin by adjusting their sights to material resources. A research policy of one's own calls for substantial funds, a privilege reserved to well-endowed foundations. More thorough investigations would doubtless show that while in all cases a considerable element of pragmatism exists, this need not rule out some specific policy approach, since it can be the result of a carefully thought-out posture not at all incompatible with the objective of innovation or of complementarity.

With the broad options come a great many decisions of a more practical but highly important kind on the types and methods of research to be adopted. Some foundations which have the means to do so may decide to set up their own research structures, building laboratories and staffing them with their own scientists.[1] Such intra-mural research can be very effective, but it runs the risk of being conducted in a vacuum: isolation interferes with the comparative evaluation which should enable a laboratory to assess its own performance; any such solitude is conducive to a falsely optimistic attitude and is too high a price to pay for independence. An independent laboratory, being marginal to the official system, has the additional disadvantages of having less influence over that system and finding more difficulty in improving it. Most foundations prefer to support extra mural research by making various kinds of grants and fellowships available. They do not want to be operational, but content themselves with providing the necessary stimulus in the research sectors they have decided to support. This will be a less spectacular, more discreet role, difficult to know well or to evaluate, but potentially of great value.

Whatever type of research is envisaged, the foundation will take no decision without adequate advice, which is all the more necessary because in the last analysis, the foundation is answerable to no-one except its own Board of Governors.

The directors of some of the major European foundations decided recently to meet periodically to brief one another about the scientific directions which their respective institutions are pursuing. This will enable them to compare their working methods and in particular, their criteria for selecting projects. A foundation cannot approach project analysis as the authorities do, but can and should allow itself to take a subjective view of a project and accept challenges that would be too risky for the State to do. The approach may appear to be a reckless one; the foundation is aware that it stakes its reputation upon such freedom of action, but it also knows that boldness is one of its reasons for existing.

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[1] This applies to the Fondation Pasteur in France.

As the foundations belong to the private sector and are generally of industrial origin, they are well able to maintain relations with the industrial world, which itself has powerful motives for research and is usually well equipped for it. But if a foundation is to play its special role, then even though it may receive regular financial support from industry, it must retain its complete independence in scientific matters or it will prove to be no more than a company laboratory.

Lastly, the foundations will have to discover ways of concerting their activities with the public, university and non-university sector which again raises the delicate problem of their relationship with the State, one which will be largely influenced by public opinion.

2. The foundations and the nation

The relationship between State and Foundation does not depend solely on the nature of their administrative connection. The question is wider and more complex, and hinges on mental processes which have grown up over the centuries among the public, though the State has also helped to shape them.[2] There are two opposing schools of thought as to how tasks in the general interest should be carried out. In some countries, among which France is an extreme case, the public feels that anything involving the general interest should be the direct responsibility of the State, since the private sector is invariably suspected of favouring individual interests and of profit-seeking. If the State leaves any such activity to private enterprise, the public regards this as a dereliction of duty and will clamour for the State to assume what is regarded as being its exclusive responsibility.

Much like the public in France is opposed to motorways built or operated by private companies, it therefore tends to condemn a private sector in research; action by the foundations in this field is regarded as an evil, one perhaps necessary in the immediate future, but only warranted by the inadequacy of public funds. Since the private sector is unprepared to take on tasks in the general interest, it may never be able to rise to the level of research in the common welfare, be motivated by considerations of temporary expediency (prestige, publicity, tax advantages) and in this way come to deserve the sort of criticism which now is only too readily forthcoming.

On the other hand, there are many other countries, especially the English-speaking countries, in which it is not the exclusive privilege of the State to define the general interest, which may also or even mainly spring of itself from the combined interests of each individual; the profit motive is regarded as legitimate; the public sees no reason why part of the money thus gained should not be devoted to charitable activities or projects in the general welfare.

Foundations need the support of the public to come into being, flourish and develop. It is therefore only to be expected that in a system of the

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[2] On this matter, see particularly the contribution of M. Pomey on the "State and Associations in the general national interest" of the collective work: *Pour nationaliser l'Etat*, Editions du Seuil, Paris, 1968.

French type, research foundations should be so few in number and so poorly endowed, the view being that this type of activity should be financed from public funds and not by individual philanthropists; the scientific community itself may appreciate some of the advantages but will be instinctively suspicious of any such parallel, competitive activity, for which it cannot see any ultimate necessity. One result may be difficulty in recruiting staff; and if the staff can be found, there may be problems of communication with the scientific main stream, which is found in public research.

Against this background, the foundations have little chance of undertaking any valid research. They will be perceived as but a temporary expedient to meet an unhealthy situation and their greatest achievement will be to contrive a return to the public fold. Their policies will always be too apt to be taken over when the opportunity arises. There may be a few shining exceptions in a country such as France, but these will either owe their existence to the State itself (like the Fondation de France) or in practice be controlled by the authorities, only too delighted at the chance of escaping for once from their own administrative rules by using the greater facilities offered by the foundation statutes (the Institut Pasteur for example).

Foundations reflect a certain climate, a community philosophy, an approach to the relationships between the State and the citizen. It is no accident that in France there are only 260, whereas Spain and Germany have more than 4,500 each, Italy has more than 2,000, Switzerland 20,000, the Netherlands more than 32,000, the United Kingdom more than 102,000 and the United States 25,000.

It is in the English-speaking countries particularly that the Foundations throughout their activity can be seen as the living proof of private initiative and of free enterprise regarded as entirely capable of promoting the common weal. It is not surprising that they should be so numerous, well endowed, and capable of playing at least a highly significant if not quantitative role.

Scientists working under a Foundation do not feel that they are betraying the general interest; instead they feel that they are helping to achieve this goal in other, equally effective ways. The Foundation does not, as might be imagined in the other groups of countries, take a patronising attitude towards the scientist. The Foundation is not dispensing relief to him and he does not feel as though it were. The Foundation is on the same side as the scientist who, in any case, usually has a determining influence within it. The scientist sees the Foundation as an instrument with which to pursue his scientific interests; he can judge it open-mindedly on the merits of the services it renders. Provided that the scientist shares the spirit of a free competition which is perhaps the only way of organising creativity, he is bound to welcome the existence of more than one source of finance and the atmosphere of emulation to which the Foundation can contribute. In a system of this kind, in which private initiative can take varied forms, the scientist will prefer the assistance of the foundation to that which industry sometimes offers as well, but can never be provide with the same guarantees of freedom and disinterestedness.

3. Foundations and the State

Public opinion determines what the relationship between Foundations and the State will be. The attitude of the State can only reflect, at least in part, national thinking.

a) *The public interest monopolised by the State*

When a country is organised in such a way that responsibility for the public interest is, by general agreement left exclusively to the State, the Foundation is regarded at worst as either pointless or suspect. Pointless because the State is already dealing with the question, and suspect partly because if the foundation does nevertheless find something useful to do, this will show up inadequacies in the public sector, and partly because if it duplicates public research, then it must have some other real purpose, i.e. the pursuit of prestige or publicity which has nothing to do with the general interest. The State will therefore be wary of the foundations and will do little to encourage their constitution or their growth; it cannot logically act otherwise since it does not believe in their function.

Tax treatment will not be particularly favourable, nor will it be particularly unfavourable, it is not even necessary to discourage foundations in such an environment, since it will hardly occur to anyone to set them up. If any do nevertheless exist, the State will always be inclined, unless it has promoted them itself for reasons of immediate convenience, to control their activities as closely as possible. It will try to guide them in the direction of the general interest, which the State itself defines and embodies.

The attitude of the foundation towards the State in such a system will be one of prudence, not through fear of administrative interference but because of the general lack of support. There is even a strong temptation to try to get the State itself to confer the hall-mark of general interest which private initiative is not deemed to confer. Much as private education in France, the foundation will often look beyond even what is required of it by law, to have itself backed by the government either by maintaining very close liaison and even endorsing its deliberations by including a number of carefully-chosen civil servants among its governors.

b) *Public interest in the hands of the citizen*

Under a system of the English-speaking type, the State has exactly opposite reasons for exercising the closest supervision, simply because the environment is so favourable that it is likely to encourage a possibly dangerous amount of proliferation. But the state will only be concerned with administrative compliance and probity, and not act in such a way as to destroy the whole purpose of the foundation.

The foundation itself feels in no way discriminated against but that its path is smoothed by a favourable environment. It will try to remain true to its ideals and to develop all the qualities which it is naturally given credit for.

To play its expected role in the field of research its programmes should be its own, and its role should be distinct from that of the State Instead of sheltering behind State sponsorship, the foundations, while clinging to their own personality, will seek to discuss and concert their decisions and will have no difficulty in doing so. Such contacts with the official sector will enable the foundation not only to decide upon its own activities in the light of government programmes but also, and especially in the case of a large foundation, to turn its dialogue with the authorities responsible for national science policy to account by influencing the latter's own decisions. The large foundations in English-speaking countries can do much in setting the guidelines of national research, an impossible and unthinkable feat in a country such as France.

The fact that some countries have powerful foundations, while others are without them, that Britain should benefit from the contribution of thousands of foundations while France has practically none, is not the most interesting fact; from the point of view of research, the main question is how the research system would differ in France and in England if the position of the foundations were other than it is today.

Even when strictly limited, the role of the foundations is very much part of the research "system" which is thus enriched by a new variable, about which the final question must be whether it does not seem to be an indispensable instrument or research.

Where research foundations are active, they do not seem to be under criticism; very much the contrary, their complementary role and their facilities for undertaking the very projects which public research could only do with difficulty are often emphasized approvingly.

This leaves the impression that the countries with foundations have an additional advantage in research and are in a more favourable position than those whose system is exclusively public. All States belonging to Western industrial society have moreover come to recognise this, since each without exception has adopted special legislation to some extent, and since the countries which are less generously endowed, such as France, have sought the help of foundations abroad. Yet they do not all see the research foundation in the same way. And it may be in those countries where foundations are least developed that their role would be the most useful in providing the system with the qualities of flexibility, speed, boldness, and mobility which are lacking.

Introducing a certain measure of pluralism into the system provides it with extra initiative and new facilities, particularly in the area of finance. But there are limits to pluralism: waste and duplication should be carefully avoided, which means that the activities of the foundations should be linked to a national base. Perhaps it would suffice to create adequate mechanisms of concertations so that in the framework of flexible research planning, closer links would be established between both public and private sectors.

As soon as the foundation makes a positive contribution to operation of the research system, room should be made for the role it is proposed it should play. While it is desirable to lay down some minimum fiscal and statutory standard based on experience so far acquired, it is necessary above all that each State, in the light of its own research system's operation, try to determine how the foundation can positively contribute. By making such an assessment the State can then decide what attitude to adopt towards the foundations, such as by encouraging them— like Italy is now doing— through considerate tax treatment.

In fact the mistake would seem to lie in setting the private against the public research sector. Both are part of the "system", and therefore ought to combine their efforts along harmonious, i.e. complementary lines in the interests of maximum effectiveness and creativity.

The foundations cannot take a neutral position in relation to official research policy; their very decision is a political action, fitting into an overall context. By acknowledging that they perform a useful public function and by granting them special status, the State will thus be recognising their dual public and private nature. While their function is to help scientific research to operate as a public service, they must do it in their own way, which is that of free private enterprise, whose resources are essentially non-governmental and management is exempt from government civil service regulations.[3]

Although this idea has not yet won acceptance in every European country, it is constantly advancing, with the result that a trend favourable towards the foundations is appearing even in the most reserved countries. Since the war a few large foundations have been created in Europe—modelled, so far as one can see, on the English and specifically the American model. The benefits which result from the intervention of private and independent funds in the research system are well-known today and argue strongly in favour of this "Third force of the process of innovation"[4] which could be constituted by the foundations, side by side with public finance and industrial research.

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[3] Milton Katz, *The Modern Foundation: Its Dual Character, Public and Private*, The Foundation Center, New York, 1968, p. 10.

[4] See K. Neuhoff, Council of Europe Round Table, 17th-19th February, 1972.

GENERAL CONCLUSION

"On the principle that charity begins at home, industry will tend to concentrate its research effort on those problems which are of the greatest concern to it and whose solution will ensure its survival. The problems of the community affect industry only indirectly although it is also interested in their solution. They are accordingly the problems to which the State should give its attention."[1] Although this statement was made in connection with Swiss science policy, it might equally apply to countries which, like the Netherlands or Sweden, expect their industries quite naturally and spontaneously to show the drive, intelligence and ability to innovate which are essential to a country's economic system. Everyone in general agrees that it is a sound principle that industry should be responsible for its own development while the State should be assigned the task of solving the "problems of the community".

In the sphere of research policy this division of responsibilities has long remained essentially theoretical. Indeed, when the need has arisen, governments have not hesitated to offer indirect and even direct support to industrial research. Furthermore, in most cases the state has made only moderate demands on science and technology to satisfy the non-economic needs of the community. As non-economic actions have been comparatively few, the national research effort continues to be predominantly devoted to the pursuit of economic growth.

In any event, the great difference between the five countries and Germany, France and the United Kingdom lies in the conduct of scientific and technological activities particularly in relation to economic activities. With comparatively slender resources, without any spectacular political mobilisation and often even without any deliberate effort, the five countries have succeeded in creating a climate conducive to innovation based on the spontaneous initiative of individuals and groups. One can even point to the Netherlands, Sweden and Switzerland as exemplary models in this connection. These countries do indeed seem in many respects to have achieved the degree of technological drive which is still being sought by other countries whose structures have often proved a difficult obstacle to innovation. It is not, however, certain whether these advantages can be retained without jeopardizing a number of principles of scientific "laisser faire" which are perhaps no longer consistent with new developments in international competition.

At the same time, new aspirations are manifesting themselves in all industrial societies, expressing the feeling that economic growth alone cannot meet all needs and that many of the new problems which industrial societies will have to face cannot be understood and solved without considerable help from scientific and technical research.

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[1] Statement by Mr E. Junod, Chairman of the Governing Body of the Swiss Union for Commerce and Industry quoted in *Review of National Science Policy - Switzerland*, OECD, Paris, 1971, p. 249.

The five countries considered have therefore been compelled to envisage developing their research efforts for non-economic purposes. The problem here, in many cases, is to set up or develop a scientific research system in fields or organisations in which it has either been vegetating or has not even existed. A further problem is to formulate the main lines of future actions and offer those concerned a number of clear ideas likely to mobilise their energies.

National traditions which placed research in the almost exclusive service of economic growth must be put to the proof in the light of the new imperatives which expect the State to reconcile the community's material prosperity with its social and moral equilibrium.

I. Research in the service of growth

For the most part, the scientific and technological systems in the five countries have traditionally tended to respond to economic imperatives. Strategic considerations may no doubt induce the state to give special encouragement to some particular field of research, as in the case of Swedish defence policy or Swiss nuclear research policy. Both in its definition and in its execution, however, such research makes full allowance for economic realities.

Industrial scientific activity is therefore the essential objective and purpose of traditional research policies in the five countries, but these policies, it may be said, continue to be unobtrusive and non-mandatory as long as firms spontaneously display a satisfactory drive and ensure national prosperity.

A scientific and technical system of this kind, however, cannot depend exclusively on industry's ability to innovate. Firms must be able to obtain the qualified personnel they need to achieve their technological ambitions and must have access to the most advanced discoveries of international research.

At the service of economic growth, research in the five countries is therefore mainly centred in industries and the universities, the part played by the State being more unobtrusive and less direct than in such countries as France and the United Kingdom. The State's task is not so much to lay down the major options or stimulate large-scale developments, but to guarantee a favourable context for exchanges between the economy and the universities, which have always been a necessary condition for cross-fertilisation. The university system has thereby acquired particular importance and it is not surprising to find that it is stimulated and oriented to a very large degree by national industries.

a) *The driving force of industrial research*

If the five smaller countries collectively are compared with the three big countries examined in Volume I, it would appear probable that the former have not only made a contribution to the advancement of science which is proportionally greater than that of the latter, but that they have utilised and applied their science with much more profit and efficiency than the big countries.

The most evident reason for this apparently is less distinction between "fundamental" and "applied" research and less contempt for the latter than one finds in more traditional "scientific communities". Some of the best researchers in industry and university have combined both, becoming "fundamental" in economically useful fields of research or looking for applications and markets for initially fundamental research results.

In addition to the general research climate, there are specific reasons for the more profitable application of research in the five countries. Some of these must be seen in the framework of the very high dependence of the five countries on international trade, which reflects their economic specialisation and which is the price they had to pay for reaching the highest standards of living in Europe.

With regard to industry, the dominating fact is the concentration of all industrial, and to some degree even all national R & D in a very few hands. In the Netherlands, Sweden and Switzerland, the five biggest companies (measured in world turnover) spend 60-65 per cent, 45-50 per cent and 70-75 per cent respectively of all industrial, and 35-50 per cent of all national R & D. This resulted from the quick growth of multinational companies based on advanced technologies; in Sweden the farming out of most defence R & D to industrial companies also played a considerable role.

In any case, the present situation was not the result of any deliberate governmental plan or strategy in the field of research, but resulted indirectly from the workings of a liberal economic system: much of the science in those countries was created to be used, or at least to be useful, which certainly cannot be said of many bigger countries. Though it is true that big companies have made mistakes in their science and technology policies which have had wider implications for their home countries, we can certainly say that on balance home countries have scientifically profited from their big corporations.

In addition, science policy in the five countries was more clearly and exclusively directed at supporting industrial R & D than it has ever been in big countries. The absence of big power ambitions obviously facilitated such a policy— another ultimate advantage of small size. It is very interesting that the one country which wanted military strength based entirely on its own industry— Sweden— succeeded through a policy which varied from that of big European countries, but imitated that of the United States: the bulk of defence research and procurement as entrusted to private companies which had already proven their capacity and efficiency.

The wish to support industrial R & D expresses itself in many institutions and policies, though their impact is more evident in Norway, where the NTNF finances a third of all industrial R & D, and least direct in Switzerland, which demonstrated this support mainly through a considerable solicitude for the Federal Institute of Technology. The other three countries are between these two extremes: in the Netherlands, the TNO laboratories helped many industries, though rather the big than the smaller ones, irrespective of their original destination; and in Sweden, where the Royal Academy of Engineering Sciences (IVA) succeeded for a long time in raising the status of engineering and industrial R & D, the STU has been for a few years the main distributor of Government funds for the support of industrial R & D.

These institutions differ from the efforts of many bigger countries in favour of industrial R & D in several respects: in the early recognition of a purpose, in relatively clear goals, and in the concentration of responsibilities and funds into one major body.

b) *The universities stimulated by industry*

The research system as described in Volume I is characterised by two features: first, a dual system of finance consisting of the general university budget— i.e. the basic institutional financing— and supplementary financing earmarked for specific projects; and secondly the twofold operational system consisting of university and peripheral institutions.

The five countries reviewed in this Volume display the first of these characteristics only. The virtually total absence of a peripheral sector is explained by the fact that these countries are too small to afford a diversified operational system for fundamental research although they often have big applied research laboratories managed by applied research councils closely connected with the technical universities.

The concentration of the scientific complex in the same environment, namely the university, has undeniable advantages over the three countries previously reviewed.[2] But the consequences are somewhat constraining: the conflicts which arise between the two university functions of teaching and research have not been eliminated. Far from it: the teaching function has prevailed, has coloured research at all levels and has even accentuated to the point of caricature the shortcomings of the university system in the three countries previously reviewed:

- in the research sector itself multidisciplinary, interdisciplinary or transdisciplinary research[3] is practically unknown in universities. Research is modelled on the map of knowledge which is based on individual disciplines and it has to conform to the structures planned for the education system;
- in point of structure, the system of organisation by faculties prevails. But the faculty is merely a formal group of scientific disciplines as defined by the nature of the curriculum. "Postgraduate" research, defined as a short and intense period of training in research, does not exist (except in Belgium where it was introduced in 1971). The strength of the faculty structure, which is a guarantee of "academic freedom", has made it impossible to work out research "policies" at the level of individual universities. The only issues which have shaped the development of universities in the last few years are student intake (and its incidence on budgets and layout) and the award of diplomas;
- at individual level, there is no system under which a research worker can devote himself exclusively to research for a limited period. But the teaching workload is growing heavier (increased

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[2] See Volume I, Part II, Chapter III.

[3] See Volume I, Part II, Introduction.

> student intake); the university Chair system which still exists (in Norway, Sweden, Switzerland and Belgium) and the inadequate increase in the number of professorial or equivalent posts conferring powers of decision and initiative have limited the possibilities of promotion. All too frequently the younger teacher-research workers are not given sufficient independence to conduct their own research at a stage in their career when their abilities are probably at their height and they are consequently apt to become discouraged and bitter. The absence of any large research team or any team spirit in universities has sometimes led to half-hearted "pottering" and has often generated a tendency to take refuge in fundamental research.

This scientific individualism is accentuated by the fact that, with a few exceptions, there is no procedure for securing collective or joint research grants as in Germany, France and the United Kingdom.

The absence of the corrective afforded by the peripheral system in Germany, France and the United Kingdom would be highly dangerous at national level if the countries concerned did not possess a number of important countervailing advantages which open up a window on the outside world and offer a chance of revitalising the traditional university. The intensity with which international contacts are being made, the importance of the links between the universities and industry and the drive of the technological universities are essential factors in this connection.

Whether because the countries concerned are very small or because they have few university posts or because of their traditionally receptive attitude to international influences, contacts with foreign countries are intense. Not only are their laboratories open to foreign research workers but, most important of all, there is hardly any young science graduate who has not spent one or more years abroad, though not so much in adjoining countries as in the United States. Similarly, the participation of their young science graduates in international congresses seems much more frequent than in the three countries previously reviewed. This is an important factor to the credit of the research councils which generously finance travel abroad.

As we have already seen, industry is often compelled to act as a peripheral sector; it fosters contacts between isolated research workers and highly differentiated disciplines and is an instrument for opening up new sectors. It would also seem that in countries where the industrial sector is developed, research workers have a foot in both industry and the universities in the course of their career.

The exceptional place occupied by technical universities in fact explains the extensive links between science and its applications in all the countries reviewed, except Belgium. The technical universities, established before the era of technological industrialisation, have enjoyed considerable prestige and have become centres of attraction for the student élite. Many of them began very early to do R & D work for industry or in close co-operation with industry and this explains why their students have been trained in intimate contact with industrial realities and have become versatile engineers. In fact, most industrial R & D (and in Norway and Sweden practically all) is done by engineers and technologists. The decision to endow the technical universities with institutes of industrial and applied research seems to have played a very positive part in this direction. There again, the initial disadvantage of their smallness has turned out to be an advantage as compared with the larger countries, for the latter have not had the same type of central technical universities which enjoy great prestige, are highly active in research and are geared to the requirements of industry.

It is therefore not surprising that in Switzerland and the Netherlands and to a lesser degree in Sweden and Belgium, this very favourable climate has stimulated industrial research which is sometimes capable of competing with university research in quality, quantity and originality. It is no less apparent that the technical universities are also contributing to enhance the general level of university research. For this purpose they enjoy undoubted advantages. They are better endowed materially (if only because of the contracts they receive from the private sector) and they are less overcrowded (owing to their competitive entrance examination). The research done by these establishments is therefore very important for the scientific and technological equilibrium of the countries concerned. Moreover, it indirectly reinforces university research as a whole by building up the prestige of technological research and fostering an atmosphere of emulation which enables science to maintain its dynamic approach and its influence.

The stimulus which university research enjoys as a result of its links with industry and because of the quality of its technological institutes is therefore undeniable. However, this cannot possibly be sufficient as a perpetual source of nourishment for university research as a whole. For example, in Belgium, Norway and even Sweden university research is not on a sufficiently large scale to ensure the mobility of research workers between sectors. The most important fact of all is that there are research sectors which are socially and scientifically significant such as biology and the earth sciences which have no counterpart in industry in most of the countries considered. It must also be pointed out that industry does not finance research regularly, is more sensitive even than the State to economic fluctuation and is also apt to succumb to the fashion of the moment.

The technological universities cannot cover the whole of the scientific map. Furthermore, their human and scientific contacts with the traditional universities are comparatively limited. These contacts are particularly slight because all the countries concerned have research councils responsible for financing applied research almost exclusively.

The stimulating influence of industry therefore does not usually extend to fields which are particularly important in the light of the new objectives which are more social than economic exigences. In this respect the public sector and private enterprise should play a particularly important part in restoring the balance. They are not yet completely prepared for this role.

II. The developing research sectors

Disequilibria may arise in university research, certain aspects of which enjoy closer links than others with the university sector. Certain fields may also be neglected if the State does not supplement industrial and university research by intervening with its own facilities to solve "problems of the community".

The research establishments in the public sector will therefore have to assume important responsibilities in opening the way for the new sectors concerned in the wider aspirations of science policy in the industrialised countries.[4] Moreover, the substantial flow of disinterested contributions from non-governmental sources— particularly private foundations— is likely to make good any disequilibrium or negligence which might arise when science is obliged to serve a number of unduly limited objectives.

The powerful research effort the authorities are in a position to make in order to serve the needs of the community has generally remained at the embryo stage like the indispensable unorthodoxy contributed by the Foundations. Nevertheless, the groundwork has been laid and a start has been made on the task of broadening research policies and enhancing research facilities in the five countries.

a) *The relative effacement of the public sector*

The first point which strikes us when we try to analyse the action of the public sector in matters of research is how widely it varies in form among the different European countries, as evidenced by the very fact that no common "pattern" can be defined. Transcending this diversity, however, the features which all governments traditionally have in common are found, regardless of the country being examined. Since functions are similar, so are the traditional fields of action, as well as related problems and trends which stem from the very nature of such fields. The "red tape" characteristic of all public bodies means that the traditional administrative rules of the government sector are basically incompatible with the kind of management suited to research institutions.

Because of certain limitations of the university and industry, likewise common to all countries, the raison d'être for government research agencies is the same in all of them. Fairly substantial practical differences in the way the function is fulfilled are, however, found when France, Germany and the United Kingdom are compared with the five countries under review. These differences have naturally crystallised around the new fields, which because of the large capital investments they need have been more accessible to the larger countries. In attaching extreme political importance to these fields, the first three countries have frequently been apt to forget that these fields did not represent any lasting functions or requirements, but merely techniques and methods, with the result that the whole raison d'être of the responsible agencies was likely to be challenged. The second group of countries, necessarily more modest in their ambitions, have thus largely been able to avoid any agonising reappraisal of policy and difficulties of conversion, but at the same time have not been able to derive as much benefit from the knowledge provided by these new fields.

Even though there has been for some years a relative but undoubted decline in these fields and even though the heroic age of technological adventures now seems to have passed, these adventures have nevertheless has a deep and lasting influence on the research system in the countries concerned. In the first place, it is unquestionable that the style of "big science" has infiltrated into fields where it would have been hardly thinkable as recently as ten years ago— a trend moreover apparent in both the methodology and management of research. From the standpoint of science policy, it is the new fields more than any other which first clearly showed the need for such policies and later their shortcomings, thus providing extremely valuable guidance for the future.

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[4] See: *Science, Growth and Society: A New Perspective*, OECD, Paris, 1971.

With the change in science policies, as described in particular by the Brooks Report,[5] the entire research system is entering a phase in which its tasks must be redefined. It is no longer called upon to display scientific or technical prowess at all costs, or to aim solely at economic growth conceived as an end in itself, but rather to meet all the aspirations of society. Traditionally responsible for the general interest and the common well-being, the government sector might well find along these lines the general sense of purpose which it still lacks if it is to overcome its present difficulties, whether they arise as in the three "big" European countries, from a questioning of the justification for public research institutes, or as in the five countries reviewed here, from a too purely negative conception of this justification; the government sector has in fact been induced to assume responsibility for scientific and technological activities and fields of national importance for which neither industry nor the universities were willing to be responsible. The resulting scale of the public research sector in the five countries is a reflection of the strength and weakness of industry and higher education.

These differences in motivation and procedure cannot, however, suffice to characterise the public research bodies in the three "major" countries as compared with the five others. For example, it is impossible to disregard the significance of differences in size; the government laboratories of the five countries are part of a scientific community of modest dimensions; recruiting first-rate research staff is difficult everywhere but in small countries it does not take very long to reach the bottom of the barrel.

Despite these obstacles to progress and adaptation, a number of developments suggest that government laboratories are likely to play an essential part as "suppliers" of the research required for social objectives owing to a revival of interest in the traditional sectors and the development of new fields.

It will be noted that certain old established sectors of state intervention, such as public health, are now of increasing importance and are being approached on an ever wider front.[6]

In the second place we are witnessing the development of what, for want of a better name, is called the environment, a field which has yet to be clearly defined, if only because it is apt to be associated with so subjective a concept as the quality of life. In some ways this is a classical field since governments, as part of their traditional role, in earlier times have taken an active part in certain environmental disciplines. In this area the smaller countries have often taken original and valuable steps which can serve as a pattern, as in the case of the Swiss Institute for the Study of Snow and Avalanches or the Water Engineering Laboratory in the Netherlands; more generally, Sweden is one of the first countries to have treated the environment as a field of special importance. In other ways it is a new field which affects extremely complex systems, overlaps many other fields and shares many of the features of big science, particularly in the matter of size; experience in the new field is consequently a valuable asset for the three "major" European countries. Environmental research, which is still in its infancy but promises to become increasingly important, may therefore be regarded as a "new classical field" in which the government sector can normally be expected to play a paramount role and where countries of any and all sizes can use and develop the knowledge they have previously acquired.

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[5] *Science Growth and Society, op. cit.*

[6] See Volume I, Part III, page 156: the term "medical research" is now being replaced by "public health"

b) *The exemplary but too limited role of the foundations*

The role of the Foundations in scientific research is so unobtrusive that it often passes unnoticed. Indeed, in certain countries Foundations are almost entirely unknown. And yet these institutions which were at the outset essentially charitable have increased in numbers in the last fifty years in all industrial countries of the capitalist system and have discovered new functions in which scientific research is playing an increasing part.

Their financial contribution does not generally amount to much in the overall research budget, but their resources which are free from official restraints are qualitatively highly important. Indeed, if the Foundations continue to be independent of the State, they may fulfil a specific function.

The Foundations are an integral if unobtrusive part of the research system— their role being to supplement the action of the other components of the system or to make good their limitations— but they are not a specific feature of the five countries reviewed. Nor can the Foundations in these five countries be compared with those in the three countries which were dealt with in the previous survey. At very most the role of the European Foundations may be compared with that of the United States Foundations. But a comparison of this kind is only possible quantitatively, i.e. with reference to the facilities at the disposal of the Foundations. They cannot be compared qualitatively for on both sides of the Atlantic their function and role have remained the same.

The differences between Foundations in one country and another lie not so much in their action, style and fields of operation, as in the extent to which the general conditions in the countries concerned are conducive to their multiplication and development. In this respect the power or role of private industry is not a decisive factor. The United Kingdom where Foundations are so flourishing might be compared with France which is the poorest country in Europe for Foundations. In Switzerland and the Netherlands where industrial research and industry are decisive for scientific development, the activity of the Foundations is not on a greater scale than in Sweden.

The factor is bound up with the outlook of the man in the street and society's conception of the public interest and the ways in which it should be served, i.e. either exclusively by the State or by a variety of private agents. It transcends the belief in the benefits of private enterprise and relates more specifically to the belief in the advantages of pluralism. Like the Stiftung Volkswagenwerk Foundation in Germany, one of the biggest Swedish Foundations i.e. that of the Bank of Sweden, was set up not by private enterprise but by Parliament from public funds and with public support. The Foundations are such an integral part of the research system in the countries in which they exist that scientists address themselves impartially to the Foundations or to the Research Councils. The idea that social well-being should be achieved by the combined action of a number of independent agents— each objective being pursued by a wide range of different agents— is characteristic of the liberal system which some of the five countries reviewed have achieved in their science policy.

The Foundations have a variety of functions. They may be said to have a complementary role and to provide supplementary funds for original research which is already financed basically. The flexibility of the Foundations and their policy of supporting research off the beaten track is clearly an asset to the scientific community which indeed is well aware of it. When they are richly endowed the Foundations may act as pioneers and open up new fields which have for one reason or another been neglected by industry or the public authorities. Medical research in the United Kingdom, pharmaceutical research in Italy and the social sciences in Italy, Sweden and even Switzerland are typical in this respect and have scored exemplary success.

But whatever may be the scope of their potential field of action, in supporting either individual researchers or whole sectors of research, the Foundations cannot be defined solely in terms of their relation to the public authorities. They may also be defined in terms of their relation to the university system which is the main performer of the research they support. In addition to the fact that the Foundations refrain from maintaining their own laboratories, and therefore have to rely on a university infrastructure generally characterised by its rigidity, it should be noted that they also have to call upon the scientific community to choose among the applications submitted to them. The problem of the Foundations is therefore to choose men who are sufficiently reliable and at the same time sufficiently unorthodox to preserve both the value and the originality of the scientific work they put their hands to. The problem is obviously more delicate in countries where the scientific community is fairly restricted and self-contained.

Before concluding, some reference must be made to a further major feature of the Foundations, namely their vitality which is reflected in a wide range of institutions with a capital endowment adequate for many branches of research. The Foundations also manifest their vitality by their fresh approach to research subjects. We have rightly stressed the way in which the Foundations act as a "lever": once they have opened up a field of research they hand it over to others who are better equipped to manage it and to finance the increased expenditure required for its development. The Foundations are sometimes even tempted to relinquish entire sectors of their action in order to ensure that "what is heresy today will be orthodox tomorrow". For example, some of the biggest Foundations in Europe consider that attention will in future have to be devoted to the social sciences and even the major policy decisions on which society will have to opt.

III. New prospects

The international trend in scientific research and the emergence of new aspirations in the industrialised societies have led to far-reaching changes in the conditions under which scientific objectives are defined and science policies implemented.

a) *Changes in scientific activity*

In the last thirty years the economic achievements of most industrialised countries have been based on a comparatively integrated infrastructure of industrial and university research which is particularly accessible to new ideas. In the Netherlands, Sweden and Switzerland the links between the national and international scientific communities have proved highly important in this respect: they have been very strong and have provided essential channels for the rapid identification and exploration of new fields. The importance of this exploratory function of the national research systems and the energy with which it has been performed by those concerned are now obvious insofar as the scientific standing of the five countries is out of all proportion to their comparatively limited resources: the "scientific area" they occupy in the mass of knowledge produced throughout the world seems far greater than their "economic space".

It may be wondered whether this very high grade research effort can still be profitably continued, particularly in university laboratories, purely by following the main trends of international scientific activity as in the past.

Several arguments seem to suggest that it cannot:

- the fact that the volume of world research cannot fail to go on growing, involving a rapid increase in the number of "lines" of research. If they attempt to follow every move in international research, scientists in countries with limited resources will court failure by dispersing their efforts;
- the development in several disciplines (such as physics) of fields which are particularly attractive to researchers despite the fact that their economic value is dubious and that they are often very expensive;
- the change in the nature of many scientific sectors where research cannot make further progress unless permanent teams are set up and equipped with instruments which require considerable capital expenditure;
- the development of international technological competition, by the emergence of new industrial branches and new countries which force national economies to make choices and to specialise more narrowly in the industrial technology sector.

These considerations suggest that scientific "laisser faire" which has long been the mainspring of research policy is not without its dangers. Looked at in this light, national efforts cannot continue to be economically fruitful unless they are based on an overall strategy defining their orientations with reference to the facilities available to them, the prevailing trend in world science and the major economic objectives.

It must, however, be noted that this opinion is not unanimously held and that the need for small countries to work out national research strategies is not always deemed to be economically urgent. In this connection the following views are generally put forward:

- one should not be misled by the quantitative expansion in world research: really promising work of high quality continues to be as rare as it ever was. Dispersion of effort is therefore no imaginary danger;
- research programmes cannot always be assessed before the event in

> the light of their economic implications. Furthermore, research which has no bearing on industry may be justified by other government responsibilities. Finally, it is purely a matter for individual firms concerned to ensure that the research which interests them is carried out.

This discussion cannot be brought to any definite conclusion in the absence of an adequate knowledge and a sufficient mastery of all the machinery of the scientific and technical system. Nevertheless, it is undeniable that the changes which have occurred in the organisation of scientific work and in the nature and scope of the facilities it requires make it necessary to reshape many research institutions, particularly in industry and the universities. An effort of this kind can only be planned and carried out under the sponsorship of the State and in the light of the national interest. It therefore necessitates the development of government decision-making mechanisms with wide powers and further investigations to ascertain the conditions under which research policies geared to economic objectives will have to be determined in the coming years. In this way a tendency common to all the industrialised countries will eventually emerge, which will induce them to attempt to work out genuine technological policies transcending their science strategies.

b) *The time for decisions*

There is a steady disinclination to consider economic growth as the one and only purpose of research, particularly in the highly industrialised countries which now fully realise its inadequacies and its nuisances. Science policy is therefore bound to consider a wider spectrum of objectives relating to the natural or socio-political environment.

The organisation of research itself cannot remain unaffected by this wider outlook and the scientific and technological problems which face the community. If research efforts are to be effective, they will call for inter-disciplinarity which present institutional arrangements— particularly in the universities— do not always facilitate. The very nature of the new objectives requires the co-operation of social science specialists and liaison between these disciplines and the other sciences is not always easy. Moreover, it is not certain whether government organisations are always capable of effectively defining their requirements in this field. Nor can it be overlooked that for a number of reasons the development of the social sciences has been much slower than that of the other disciplines.

These changes are likely to have a considerable influence on advanced research. Indeed, the orientation of the latter will have to take account of these new objectives in industry and the universities. New institutions will also have to be developed in the public and private sectors to supervise the investigation of new fields. Objectives cannot be allowed to multiply indefinitely and stricter budget and strategic options will from now on be necessary. A strengthening of the central machinery is therefore inevitable everywhere, not only to supervise the overall co-ordination of an increasingly diversified scientific and technical effort, but to see that it is guided in the direction of the major priorities adopted.

It is nevertheless a fact that the five countries under review have their own characteristics which are bound to colour the solutions they evolve for these problems of re-adjustment. Unlike most of the major industrialised countries they have not, for example, assumed responsibility for large-scale technological developments which would make it impossible to reallocate resources without demobilising considerable numbers of scientific personnel and engineers.

Above all, their capacity for technological innovation has been fully demonstrated in the industrial field. Will they succeed in harnessing this capacity, with the same energy, to the solution of their major socio-economic problems? Will they be able to equip themselves with institutions capable of making the most rigorous and essential choices and yet avoid paralysing unofficial initiative with red tape?

This, finally, is the real challenge which these countries will have to meet and it presents no small problem. However, it is conceivable that the introduction of machinery capable of orienting a system with a far-reaching capacity for innovation will be easier than the task facing other countries, which is to create an outlook conducive to invention and the spread of innovation in order to implement a policy of pre-defined research. Administering and channelling dynamic forces is, when all is said and done, easier than stimulating undynamic structures.

At all events, the scientific and technical efforts of the smaller countries seem better calculated to make a success of these difficult adjustments and should offer opportunities for a wide range of experiments. As they pursue their quality objectives, will the small countries soon be offering models as exemplary as those they have already produced in the economic field?

Without attempting to give an immediate reply to this question, we may emphasize that all the industrialised countries are facing the same exigencies. In any case the scientific laisser-faire of past years seems to be doomed as a result of the new material and intellectual needs. *All research systems must adapt at all levels.* This exigency is far from being specific to the five countries we have just examined. This is the general problem which will be considered in the third volume of this study in which the present and future pre-occupations of the major industrialised countries of the OECD will be related to one another.[7]

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[7] *The Research System, Volume III, Europe and North America - The New Options* (to appear in 1974).

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